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**DEVELOPMENT OF TERMINATION AND UTILIZATION
CONCEPTS FOR FLAT CONDUCTOR CABLES**

Volume I

Development of Low-Profile Flat Conductor Cable Connecting
Device and Permanent Splice

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July 1972

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of information exchange. Responsibility for the contents
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Prepared under contract NAS9-12062 by
THE BOEING COMPANY
Seattle, Washington 98124

for

Manned Spacecraft Center, Houston
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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FOREWORD

This is volume I of a three-volume report prepared under contract NAS9-12062, "Development of Termination and Utilization Concepts for Flat Conductor Cables."

The other two volumes are:

Volume II Utilization of Small-Gage-Wire Round Conductor Cable
(D6-40711-2)

Volume III Cost Study Comparison, Flat Versus Round Conductor Cable
(D6-40711-3)

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CONTENTS

	Page
SUMMARY	1
INTRODUCTION	2
DESIGN CONCEPTS	3
FABRICATION	20
TEST PROGRAM AND DATA ANALYSIS	43
CONCLUSIONS	66
RECOMMENDATIONS FOR FOLLOW-ON	69
APPENDIX A—Process Specification for Low-Profile Connecting Device	72
APPENDIX B—Process Specification for Permanent Splice	81
APPENDIX C—Process Specification for Transition Splice—MTSM	90
APPENDIX D—Test Plan and Evaluation Requirements for Low-Profile Connecting Device and Permanent Splice	106

DEVELOPMENT OF TERMINATION AND UTILIZATION CONCEPTS FOR FLAT CONDUCTOR CABLES

Volume I

Development of Low-Profile Flat Conductor Cable Connecting Device and Permanent Splice

**The Boeing Company
Seattle, Washington 98124**

SUMMARY

This report covers the development of low-profile flat conductor cable (FCC) connecting device and FCC permanent splice methods. The design goal for the low-profile connecting device was to mate and unmate FCC harness to a typical spacecraft component with a maximum height of 3/8 in.

The results indicate that the design, fabrication, and processing of the low-profile connecting device are feasible and practical. Some redesign will be required to achieve the goal of 3/8 in. Also, failures were experienced subsequent to salt spray and humidity exposure.

Five different FCC permanent splice methods were considered. Subsequent to evaluation of these five methods, two design concepts were chosen for development tests. One concept consists of a "boxed" concept using a molded box, sealed with an encapsulant, and incorporating pierce-through insulation crimp terminations for both FCC to FCC and FCC to RCC. The second concept consists of a multiple termination splice module (MTSM) employing the shrinkable-sleeve principle and designed for FCC configurations. It uses a meltable liner for sealing, and has solder terminations where the shrinkable sleeve, meltable liner sealant, and solder terminations are all processed simultaneously with the application of heat.

Consistent results were obtained relative to termination millivolt drop (MVD) with both techniques, but the MTSM unit using soldered terminations had a much lower MVD than the pierce-through crimp termination. Both concepts experienced some percentage of failure during dielectric tests subsequent to humidity exposure. Fixes were made on the MTSM design and improved results obtained. Further design work and development tests will be required to ensure fully satisfactory FCC permanent splice products.

INTRODUCTION

The advantages of flat conductor cable (FCC) over conventional wiring systems are well documented and cover a wide area but bear main emphasis in:

- Cost savings—Brought about by significant reductions in fabrication costs because of minimal cutting and coding, simple bundle fabrication, possibility of gang termination, and ease of installation.
- Space savings—Proven in present-day applications of FCC in special components that could not have been miniaturized without FCC.
- Weight savings—Made possible by the superior mechanical properties of FCC that permit use of smaller gage conductors.

This program was directed at

- Development of a low-profile connecting device directly terminating the FCC
- Development of permanent splices that allow FCC to be spliced to FCC circuits as well as to conventional round conductor cable (RCC).

The results of the program contribute significantly to general application of FCC and will enable FCC to (a) be terminated directly, economically, and effectively to connecting devices so that typical electrical components (relays, circuit breakers, audio or visual indicators, etc.) can be plugged in, thus increasing maintainability; (b) be repairable and accommodate changes through use of the FCC-to-FCC permanent splice; and (c) interface with equipment centers (black boxes, etc.) supplied with round connectors, through use of the FCC-to-RCC permanent splice.

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DESIGN CONCEPTS

This section covers the concepts originally proposed and discusses the selection for development into test hardware to meet the program requirements.

LOW-PROFILE CONNECTING DEVICE

The approach taken in developing a low-profile connecting device was to define a standard plug-in termination (style, not configuration) that would satisfy the requirements of the typical aerospace electrical components with which it has to interface. Existing "typical" components—relays, contactors, indicators, etc.—have alternative terminals available, such as pin, eyelet, solder hook, turret, etc. The design selected was limited to a plug-in device with pin terminations and with modifications permitted only on pin layout and pin diameter, the fabrication techniques and processes were to remain unchanged and be repeatable.

In a survey of typical components, it was ascertained that pin terminals were available or could be made available on the component, and a Leach 4 PDT 15-amp relay (K-DA-017) was selected as a typical component. Its pin terminal size is 16 (0.062 in. diameter) on a 0.200-in. grid spacing. AWG 21 flat conductor cable (FCC) on 0.200-in. centers was chosen for circuit wiring; this enabled the circuit to be directly terminated to socket contacts suitably spaced on a 0.200-in. grid spacing.

The termination was potted and contained in an insulated housing or case (fig. 1).

On devices with pin spacings other than 0.200 in., it is considered practical to interpose an etched flexible circuit between the device and the FCC. The etched flexible circuit can then be directly terminated at one end to the socket contact (domed end) and the other to the FCC with the permanent splice also developed under this program.

PERMANENT FCC TRANSITION SPLICES

Concept Description

Major considerations in the development of permanent splices were producibility, reliability, fabrication on vehicles, cost, space, and weight. These considerations were in addition to the technical performance of the splice.

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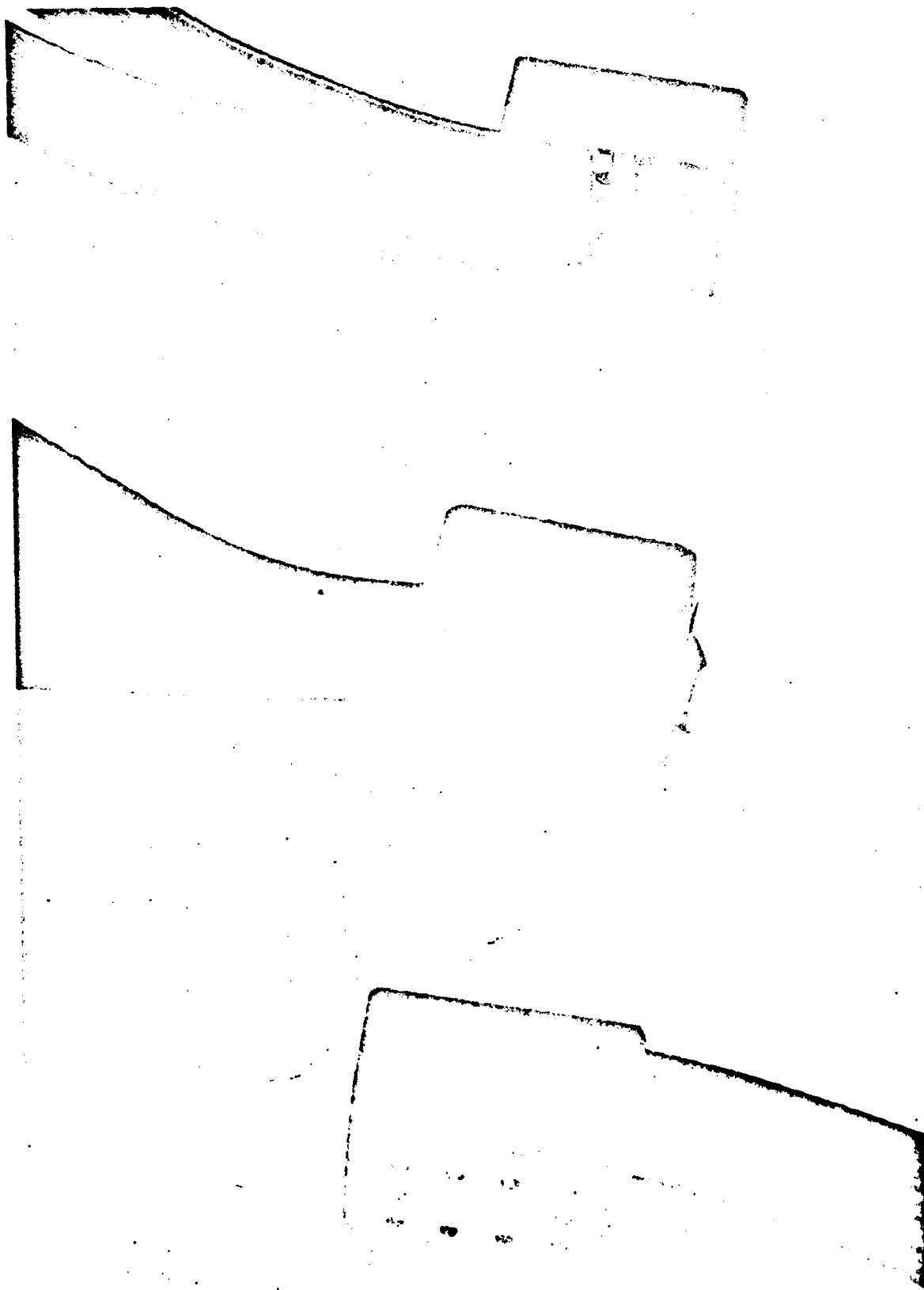


FIGURE 1.—LOW-PROFILE CONNECTING DEVICE

The major design goals for the splice were to have electrical (contact resistance, contact stability, and insulation level) and mechanical (tensile strength) properties equal to or better than the original cable. Accordingly, effort was directed toward achieving the ideal in providing the lowest possible contact resistance with low creep and, hence, high stability and an insulation seal that would protect the contact against environmental exposure.

Electrical contact can be achieved by

- Crimping, including insulation pierce-through
- Soldering
- Pressure contact

Environmental design required that each contact be insulated from each other and that all the contacts be environmentally sealed. Concepts investigated are:

- Heat-shrinkable tubing
- Primary encapsulation with Kapton film/epoxy glass fiber
- "Boxing" with epoxy and sealant
- Connector-type shells with O-ring-type sealing gaskets

Details of the concepts considered in this program follow.

FCC-to-FCC Concepts

Concept 1 (see fig. 2).—This concept employs a pierce-through insulation crimp specially developed for splicing FCC to FCC or for splicing individual flat conductor wire as may be required in a repair operation. Prototype tool designs for hand crimping in place indicate feasibility.

The advantages of a crimp-through insulation concept are many. In particular, insulation supports the crimp joint, propagation of insulation cuts is avoided, interconductor insulation integrity is maintained, stripping is eliminated, and production cost is decreased.

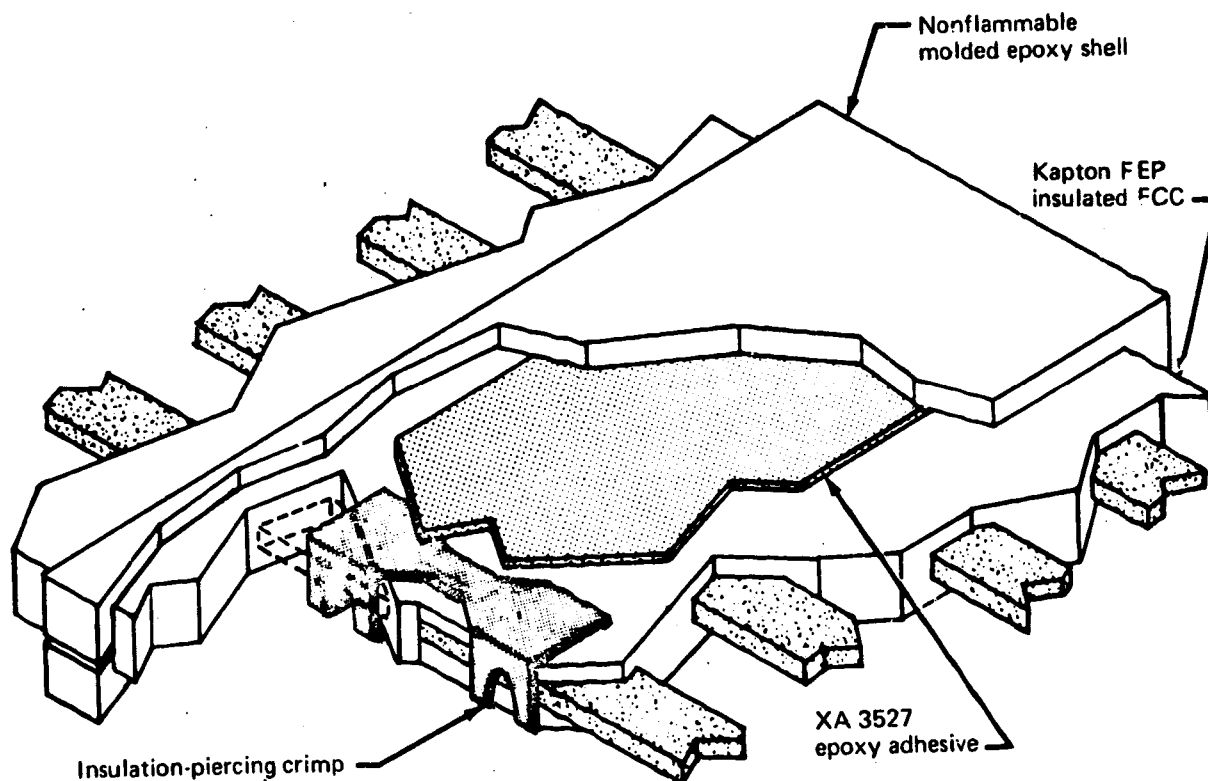
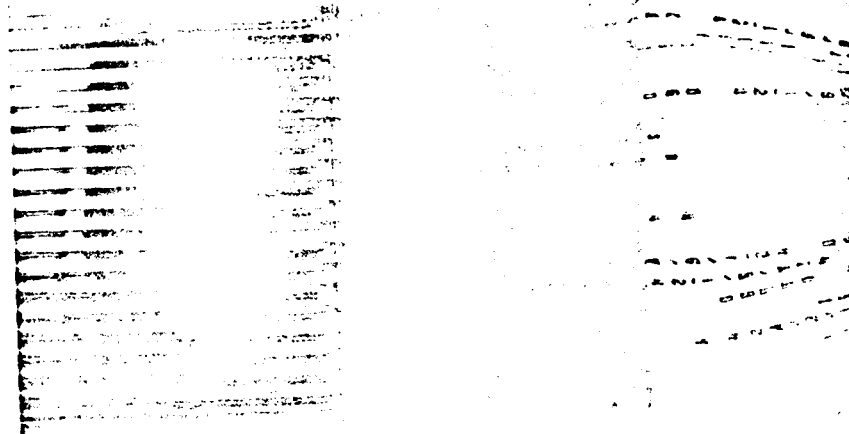


FIGURE 2.—CONCEPT 1—PIERCE-THROUGH CRIMP

Of the following approaches, the “boxing” concept was used to provide an insulation seal for the spliced cable or for individual spliced conductors.

- “Boxing” with a molded epoxy case and sealant (see fig. 2): The epoxy case is molded in two halves. Each case half is filled with uncatalyzed epoxy, and catalyzation is initiated prior to mating when the molded halves are placed over the splice area and hand clips applied for the duration of the cure time.
- Primary encapsulation with Kapton film/epoxy glass fiber (see fig. 3): This process is presently limited to the shop since the technique employs high pressure (approximately 300 psi) and temperature (approximately 250°F). However, a portable hand-held tool (heated pressure platen) appears practical.

The process after the splicing operation entails layering the splice area with laminates of Kapton film/epoxy glass fiber (B-stage, which is a preimpregnated glass cloth) and applying pressure and heat via silicone buffers so that indentations are compressed and the encapsulant takes the contours of the splice area intimately. The number of B-stage layers dictates the degree of flexibility desired.



**FIGURE 3.—KAPTON FILM/EPOXY GLASS FIBER ENCAPSULATION—FCC TO RCC
(SAME FOR FCC TO FCC)**

Concept 2.—This is also a “crimped” approach, as shown in figures 4 and 5, which show crimped splices with adapted splice tools—one for shaping the conductors to be spliced into U’s and another that applies a double crimp to a wire splice similar to a standard round wire splice.

Alternatively, a Signa Point crimp can be used effectively. Signa Point terminations are proprietary terminations fabricated by Ansley (a subsidiary of Thomas and Betts Corp.) employing powder metallurgy so that the terminations can exactly match the expansion and contraction of the parts to be terminated. It is a crimped termination that is gas tight and therefore of high stability.

In both approaches, owing to the larger dimensions, a staggering technique must be employed so as to increase the splice-to-splice distance to ensure satisfactory insulation.

Concept 3.—This multiple termination splice module (MTSM) concept (fig. 6) employs the shrinkable sleeve principle but with specially designed components for the FCC and the environments.

The “memory” imparted to the sleeve ensures that, when the sleeve is reduced by heat, it returns to the designed parameters, i.e., rectangular form for FCC, and takes the shape, intimately, of the component to be covered.

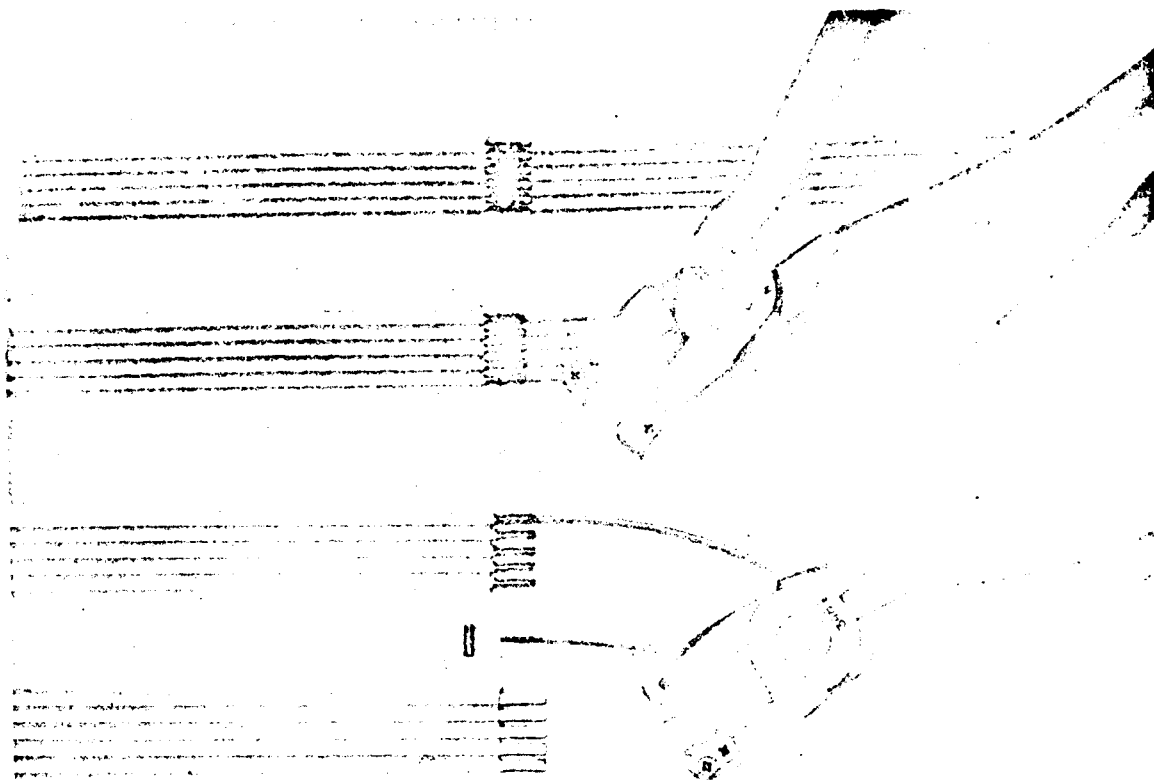


FIGURE 4.—CONCEPT 2—CRIMP SPLICE (PROTOTYPE CRIMPING TOOLS)

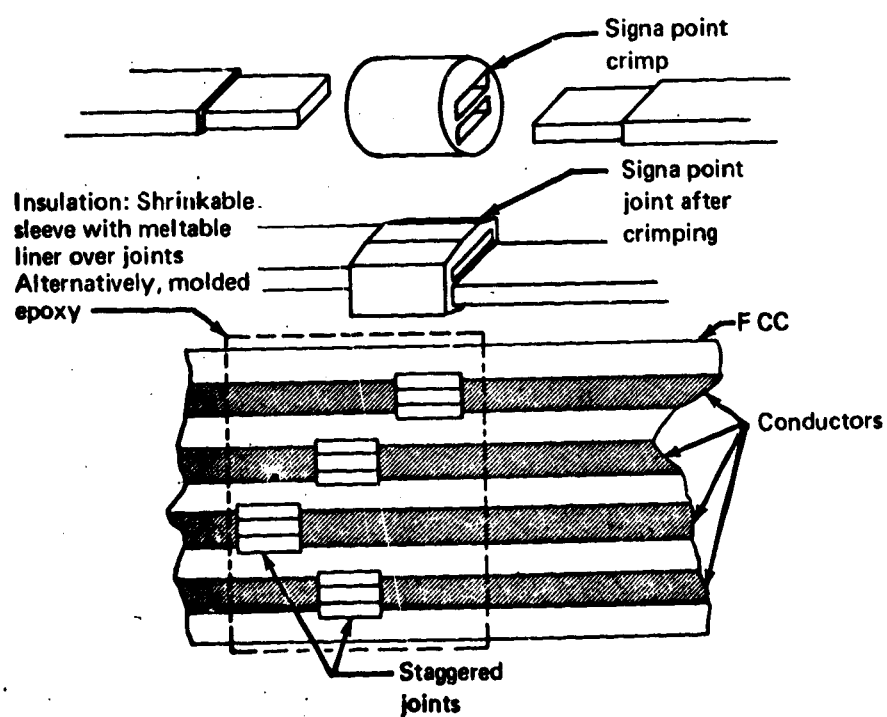


FIGURE 5.—SIGNA POINT CONCEPT

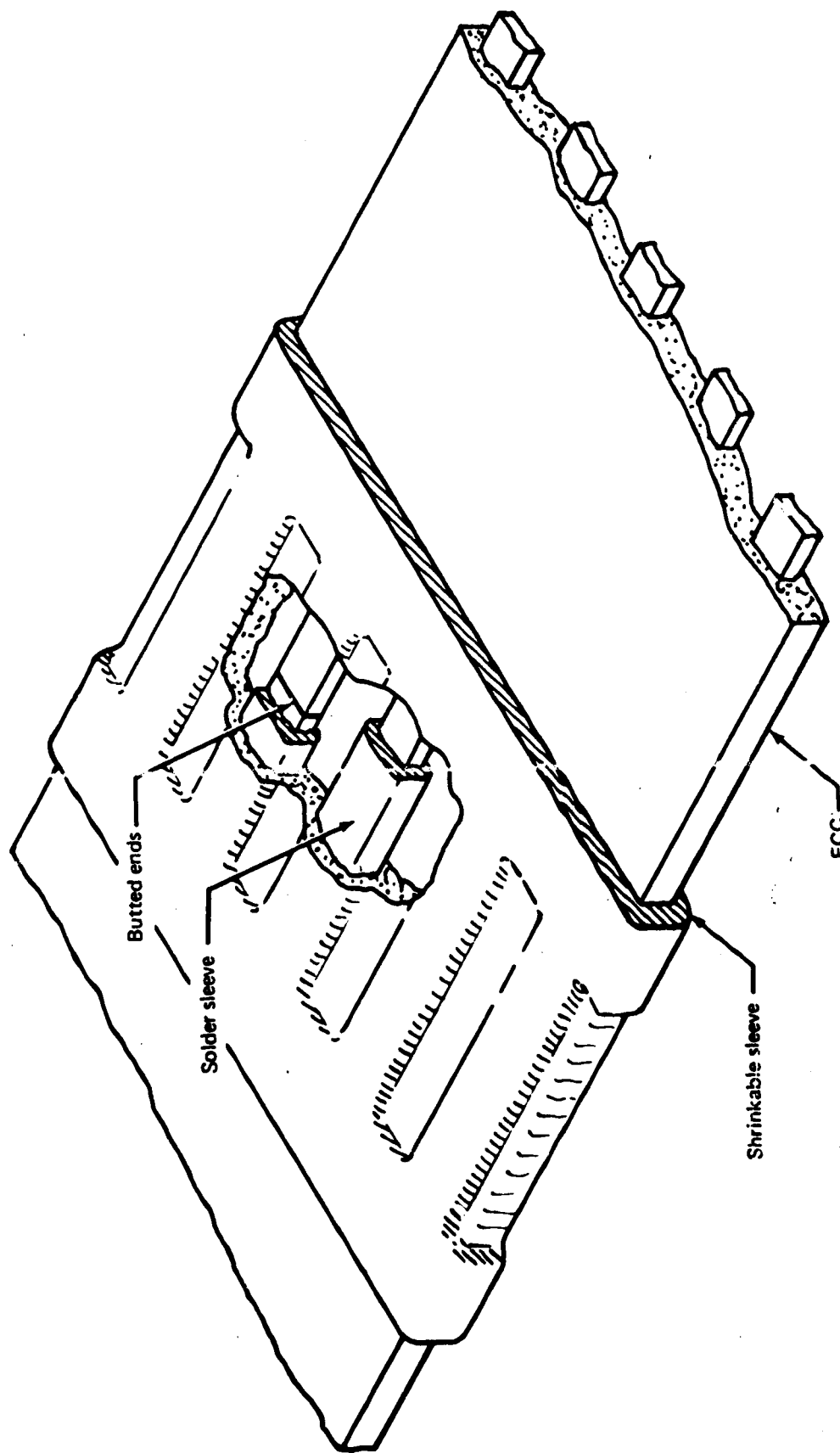


FIGURE 6.—CONCEPT 3.—SHRINKABLE SLEEVE AND SOLDER TECHNIQUE—MTSM

Figure 6 gives details of the concept, which consists, essentially, of a special contact configuration that allows the FCC to be butt joined by reflow solder on application of heat via platens or blankets that are cool on the outside surfaces. The heat also shrinks the insulation around each individual conductor/splice and the meltable liner seals the base where the individual conductor meets the uncut cable at the stress relief area. It should be noted that the specially designed solder joint to achieve the butt joint has pressure applied on it during the solder process to ensure the best possible contact.

Concept 4.—This is the Taperlok contact conception (fig. 7) in which the individual conductors are used as contact surfaces for cable extension application. For a repair application where the FCC must be bridged, a contact half is provided that locks the FCC to the housing and, when the two halves are mated, provides a good contact surface.

This concept employs three components, one for each flat conductor cable end and a housing that would apply the necessary contact pressure and retention mechanism and, by judicious location of O-ring seals, effectively seal the components within the housing. A means of holding the conductors in place and a means of stress relief are provided. Consideration was given to a pierce-through bridge member to effectively lock the conductors in place and at the same time provide intimate contact at designed points and ensure contact stability. Conductor penetration is desirable to overcome oxidation problems on the conductor/contact faces.

Concept 5.—This is another approach to a pressure contact that employs a conductor-piercing bridge contact that also pierces the insulation (fig. 8). There are four components: the rigid housing with the bridge contacts for each conductor, a conductor-shaped sliding piece that provides initial precrimp, and, finally, the tapered "Slidelok" piece that provides pressure and the ultimate lock in the permanent splice.

The problem is to provide satisfactory and uniform pressure on the number of contacts within the given FCC.

No attempt has been made to show environmental sealing, but connector-type seals and the use of adhesives is visualized.

Concept 6.—It was never intended to take this concept beyond exploring the feasibility of applying ultrasonic welding techniques to making fully environmentally protected permanent splices.

While ultrasonic welding of metals and the fusion of plastics have been successfully proven in the shop, no attempt has been reported on an operation such as projected for first welding the conductors and finally welding the plastic encapsulation. One of the problems is the effect of ultrasonic cycles on

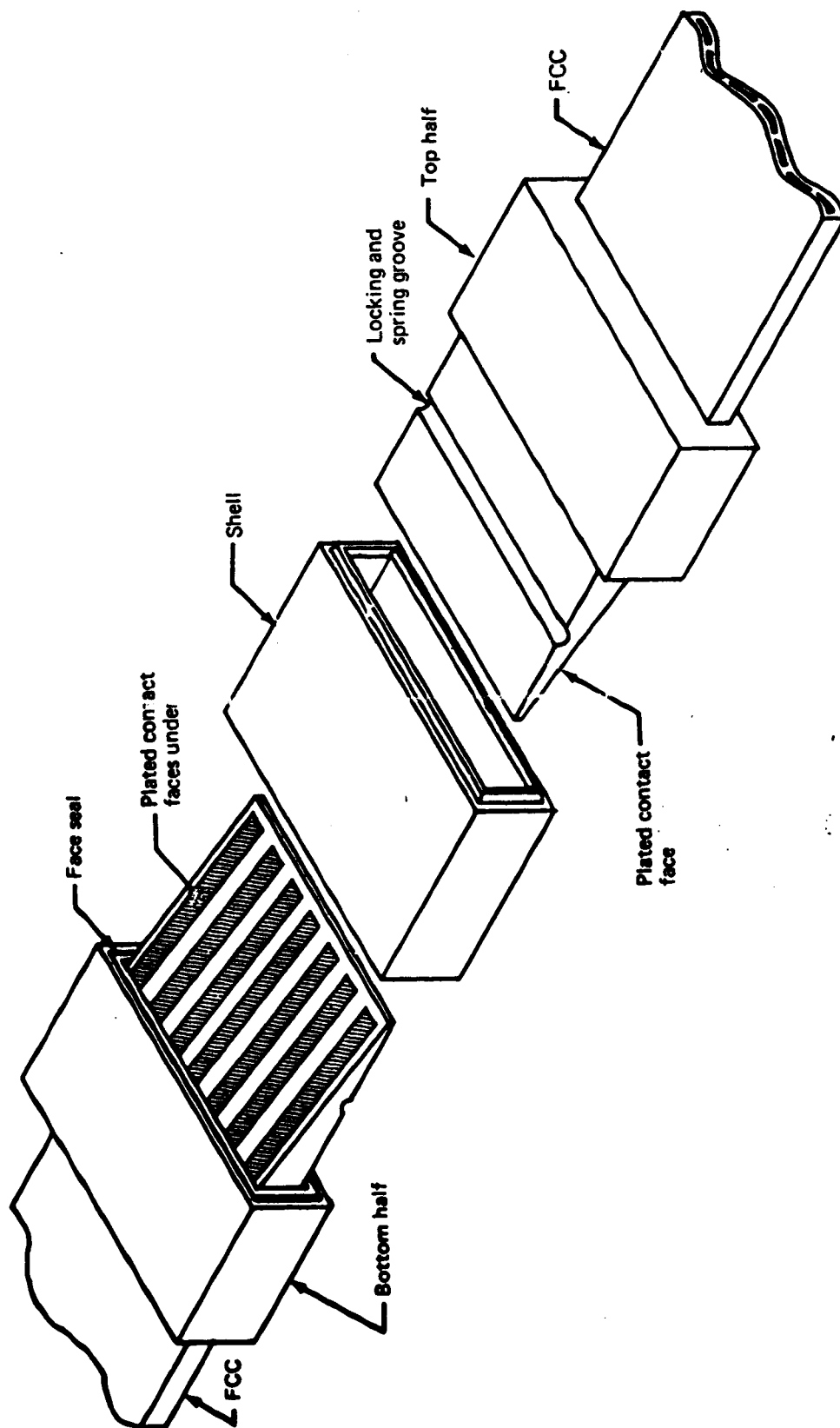


FIGURE 7.—CONCEPT 4—TAPERLOK PRESSURE CONTACT

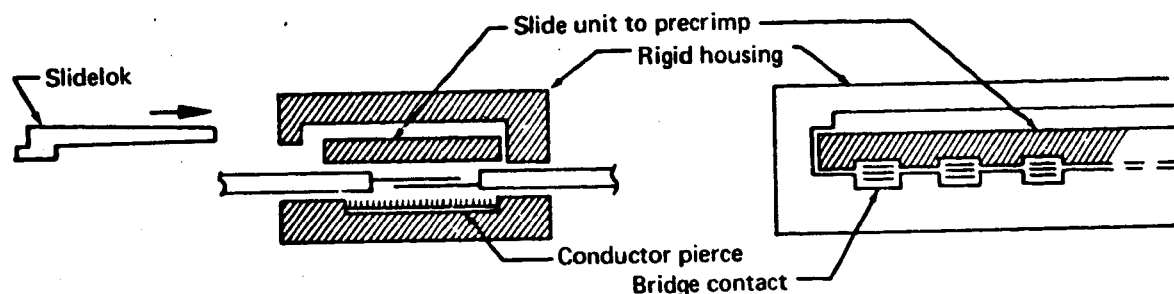


FIGURE 8.—CONCEPT 5—SLIDELOK PRESSURE CONTACT

the conductor/insulation (FEP/H-film) boundary and other interlayer boundaries. Further, it is not known if the ultrasonic generator, horns, and ancillary equipment can be made readily transportable and suitable for operation in a vehicle.

It was not possible to explore this concept because the unit available did not have the capacity required. Also, support could not be obtained from outside sources during the period of the contract.

FCC-to-RCC Concepts

In the area of transitions from FCC to RCC, it was desirable to develop the same concepts as for FCC to FCC. Therefore, the concepts investigated for FCC to FCC were considered for FCC to RCC, with some modifications to adapt for RCC.

Concept Selection

In evaluating the five concepts, the following considerations were of prime importance:

- **Electrical contact**
- **Insulation**
- **Physical Properties**
- **Producibility**

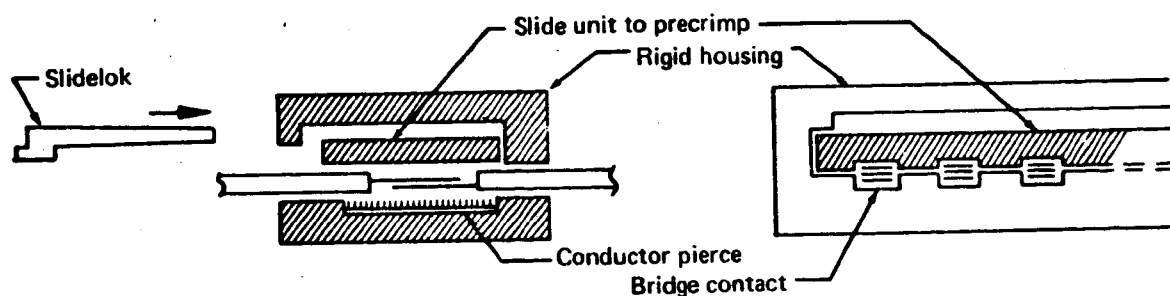


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Concept Selection

In evaluating the five concepts, the following considerations were of prime importance:

- **Electrical contact**
- **Insulation**
- **Physical Properties**
- **Producibility**

- Application to repair functions
- Cost
- Weight

The system used for evaluation was to match each concept against the others individually. The better of the two was given 1 point. Table 1 is an example of the system, based on the evaluation of electrical contact of each concept.

TABLE 1.—CONCEPT EVALUATION—GENERAL

		Concept				
		1	2	3	4	5
Points	1 vs 2	0	1			
	1 vs 3	0		1		
	1 vs 4	1			0	
	1 vs 5	1				0
Total		2				

^aFor concept 1; concept 2 is then matched against each of the others in the same manner, followed by concept 3, etc.

Electrical Contact

In this evaluation, the ideal contact is constant and has conductivity and mechanical strength equal to or better than the original wire. Emphasis was placed on consistent values over a period of time after thermal cycling and vibration. However, it should be borne in mind that the points allocated were not based on laboratory test results but on analysis and engineering judgement. The results are tabulated for easy comparison in table 2.

Insulation

The criterion used to evaluate the insulation was whether it provided complete environmental sealing of the splice area and between individual contacts and conductors within the splice. (See table 3 for results.)

Physical Properties

Physical properties considered desirable included the ability of the spliced joint to withstand normal wear and tear during installation and as installed. Accordingly, scrape abrasion, impact resistance, flexure life, and vibration were each evaluated. (See table 4 for results.)

TABLE 2.—CONCEPT EVALUATION—ELECTRICAL CONTACT

Concept No.	Description	Discussion	Points
1	Pierce-through insulation contact and "box" insulation system	The pierce-through insulation crimp contact is rated at 2. Limited test data indicate a consistent contact resistance. The effects of extended thermal cycling and vibration are not known, e.g., will this cause crimp relaxation?	2
2	Signa Point with "box" insulation system	This powder metallurgy crimp termination can be fabricated to match the expansion and contraction of the wire. A gas-tight crimp joint is possible, and good contact stability is anticipated.	4
3	Solder sleeve with heat-shrinkable insulation technique (MTSM)	Satisfactory usage record. Controlled quantity and temperature results in joints being repeatable in process and quality.	3
4	Taperlok	Demands close-tolerance conductor thickness and "clean" surfaces for good contact. Difficulty with maintaining constant contact pressure. Effects of plastic flow are not known.	0
5	Slidelok	Similar to concept 4, except the asperities would improve contact characteristics. Plastic cold flow must be compensated.	1

TABLE 3.—CONCEPT EVALUATION—INSULATION

Concept No.	Description	Discussion	Points
1	Pierce-through insulation contact and "box" insulation system	Limited experience showed acceptable results are obtainable. There could be sealing problems, particularly in the FCC-to-FCC application.	3
2	Signa Point with "box" insulation system	Because of bigger splices, staggered contents will be necessary. More difficult to seal.	2
3	Solder sleeve with heat-shrinkable insulation technique (MTSM)	Heat-shrinkable sleeve insulation technique has a reasonably long history of satisfactory usage. Considered to be potentially the most promising approach.	4
4	Taperlok	Intraconductor/splice sealing will be difficult. Close tolerance control is important.	0
5	Slidelok	Same as concept 4, but has greater dielectric separation.	1

TABLE 4.—CONCEPT EVALUATION—PHYSICAL PROPERTIES

Concept No.	Description	Discussion	Points
1	Pierce-through insulation contact and "box" insulation system	The crimped contact and the encapsulation or boxed insulation are mutually supporting and would give a "tough" splice.	2
2	Signa Point with "box" insulation system	Same as concept 1 but more bulky.	1
3	Solder sleeve with heat-shrinkable insulation technique (MTSM)	The soldered joint, bridged and supported by ETP copper insert, with a fully recovered heat-shrunk jacket around each conductor, is well supported. The comparatively thin jacket makes it less tough than concept 1.	0
4	Taperlok	The possibility of employing durable and tough plastic shells gives this concept physical superiority.	3
5	Slidelok	Same as concept 4.	3

Producibility

In evaluating producibility, consideration was given to preparation requirements, simplicity, number of steps to effect a splice, and effectiveness of insulation. Also, the ability to repeatedly produce the same acceptable quality was considered. (See table 5 for results.)

Application to Repair Functions

In this assessment, the concern was whether the concepts could be applied to repairing (splicing) individual or single conductors and to splicing several conductors in a cable. This applied to FCC to FCC and FCC to RCC. (See table 6 for results.)

Cost

The cost ratings in table 7 are considered reasonable estimates.

Weight

The weight factors shown in table 8 are based on an evaluation of materials required for each concept.

TABLE 5.—CONCEPT EVALUATION—PRODUCIBILITY

Concept No.	Description	Discussion	Points
1	Pierce-through insulation contact and "box" insulation system	The insulation pierce-through crimp will require no cable preparation. The automatic crimper in the shop floor and the hand tool for crimping on fueled vehicle makes the crimping operation simple and repeatable. The boxed insulation requires cable preparation and cure time.	3
2	Signa Point with "box" insulation system	Signa Point requires FCC preparation. Each conductor must be individually crimped. Insulation is as in concept 1.	2
3	Solder sleeve with heat-shrinkable insulation technique (MTSM)	This concept is simple and repeatable but demands cable preparation. Careful orientation of the butt ends in the sleeve packet is mandatory. Controlled heat and process time is critical but controllable.	4
4	Taperlok	Demands careful preparation of the conductors for good contact surface and also a fixture or jig to ensure proper location of conductors. The total concept would demand costly parts to cover a small range of cable width and thicknesses and would demand special adaptors for splicing to round wire.	0
5	Slidelok	Similar to concept 4, but it requires fewer components.	1

TABLE 6.—CONCEPT EVALUATION—REPAIR

Concept No.	Description	Discussion	Points
1	Pierce-through insulation contact and "box" insulation system	No cable preparation is required; hand-crimp tool is available; the simple insulation system compensates for the time required.	4
2	Signa Point with "box" insulation system	Some cable preparation; hand-crimp tool is available. Insulation used is same as in concept 1 above, but more bulky.	2
3	Solder sleeve with heat-shrinkable insulation technique (MTSM)	Cable preparation is required. Reduced temperatures with resulting increased time are required for processing in fueled vehicle. Special tooling is required.	3
4	Taperlok	Does not have ability for individual splice or breakout.	0
5	Slidelok	Same as concept 4.	0

TABLE 7.—CONCEPT EVALUATION—COST

Concept No.	Description	Discussion	Points
1	Pierce-through insulation contact and "box" insulation system	Stamped contacts are inexpensive. Automatic crimping is economical. This is a simple insulation concept.	4
2	Signa Point with "box" insulation system	Special crimp sleeves are required (power metallurgy) thus costly. Hand crimping is economical. This is a simple insulation concept.	2
3	Solder sleeve with heat-shrinkable insulation technique (MTSM)	Well-controlled presoldered sleeves and shrinkable insulation require costly development. Ganged termination is cost effective.	3
4	Taperlok	Costly tooling and close tolerances are required.	0
5	Slidelok	Same as concept 4, but to lesser degree.	1

TABLE 8.—CONCEPT EVALUATION—WEIGHT

Concept No.	Description	Discussion	Points
1	Pierce-through insulation contact and "box" insulation system	Fairly weight effective.	3
2	Signa Point with "box" insulation system	Same as concept 1, but more bulky	2
3	Solder sleeve with heat-shrinkable insulation technique (MTSM)	Lightest concept	4
4	Taperlok	Bulky	0
5	Slidelok	Bulky	1

Summary

The evaluation resulted in selection of concepts 1 and 3 for development into test hardware. A weighting factor was assigned to each consideration item (contact, insulation, etc.), so it was assessed against each of the other items on the same basis. Thus, "contact" was given 6 points, "insulation" 5, "physical properties" 0, "producibility" 4, "application to repairs" 3, "cost" 2, and "weight" 1 for a total of 21 points. The weighting factor for each item equals points divided by 21. These weighting factors were applied to the points obtained by each concept (tables 2 through 8) and summarized in table 9.

TABLE 9.-CONCEPT EVALUATION-SUMMARY OF RESULTS

Concept		Item and weighting factor							
No.	Description	Contact 0.285	Insulation 0.238	Physical properties 0	Produc- ibility 0.191	Applica- tion to repair function 0.143	Cost 0.096	Weight 0.048	Total points
1	Pierce-through insulation technique--modified from A-MP Unyt insulation with "box" concept or Kapton laminate	0.57	0.714	0	0.573	0.572	0.382	0.149	2.9
2	Crimp sleeve or Signa Point insulation as in concept 1 above	1.14	0.476	0	0.382	0.286	0.191	0.096	2.57
3	Raychem solder pak technique with shrinkable sleeve insulation	0.855	0.944	0	0.764	0.429	0.286	0.192	4.47
4	Taperlok	0.0	0	0	0	0	0	0	0
5	Slidelok	0.285	0.238	0	0.191	0.143	0.096	0.048	1

FABRICATION

LOW-PROFILE CONNECTING DEVICE

The design goal was to develop a low-profile connecting device that would mate and unmate the FCC to a typical spacecraft component. A maximum height of 3/8 in. was considered a desirable objective.

Design, Drawings, and Materials

The design concept selected is given in figure 9, which shows the device plugged into a Leach 4 PDT relay complete with spring clamp.

The face of the interconnecting device is drilled to match the pin configuration of the selected component (Leach 4 PDT relay). The drilled holes are made suitable for size 16 contacts (0.062-in. diameter). The socket contacts were modified from BAC C47DJ crimp socket contacts with the crimp barrel cut off as shown in figure 10. The socket contacts are press fit into the 1/8-in.-thick glass/silicone face and the dome end solder tinned, ready for accepting the stripped FCC.

Each row of sockets is terminated by soldering the four-conductor AWG 21 flat cable. A glass/silicone cover is emplaced and the sealant, Sylgard 184, poured to encapsulate each socket/FCC termination.

Figure 10 shows component parts making up the low-profile connecting device.

Selection of materials was based on the ability to function within the environmental requirements, availability, machinability, and bonding properties. It is assumed that production parts will be molded.

Difficulty was experienced in obtaining short socket contacts suitable for the size 16 pins, so, to meet the time schedule of the contract, it was decided to modify BAC C47DJ crimp socket contacts, which are available off the shelf.

Design deficiencies using the modified 0.062-in., size 16 contacts are as follows:

- The modified socket measures approximately 3/8 in., which is longer than the 1/4-in. required for the 0.062-in. relay pin.

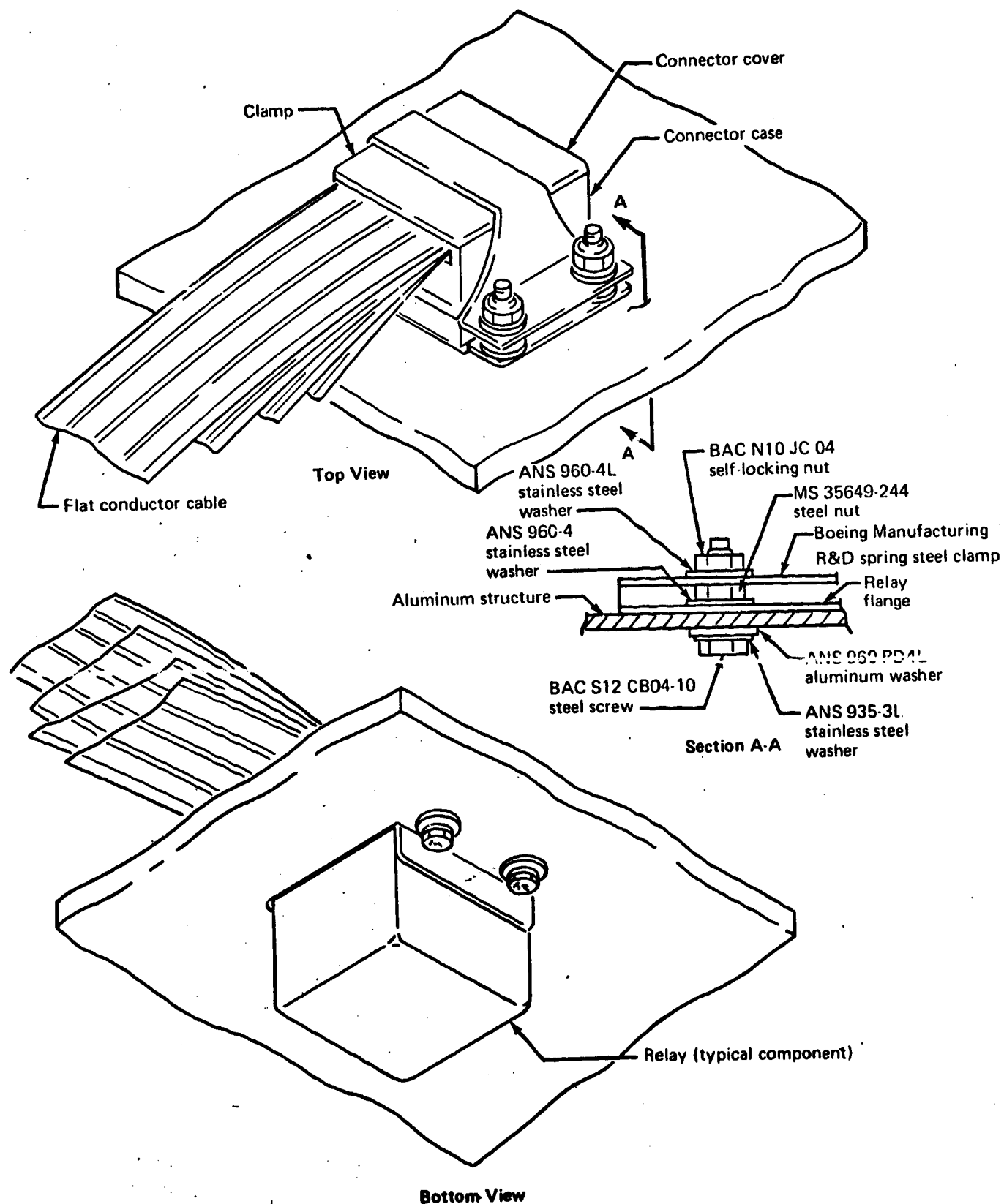
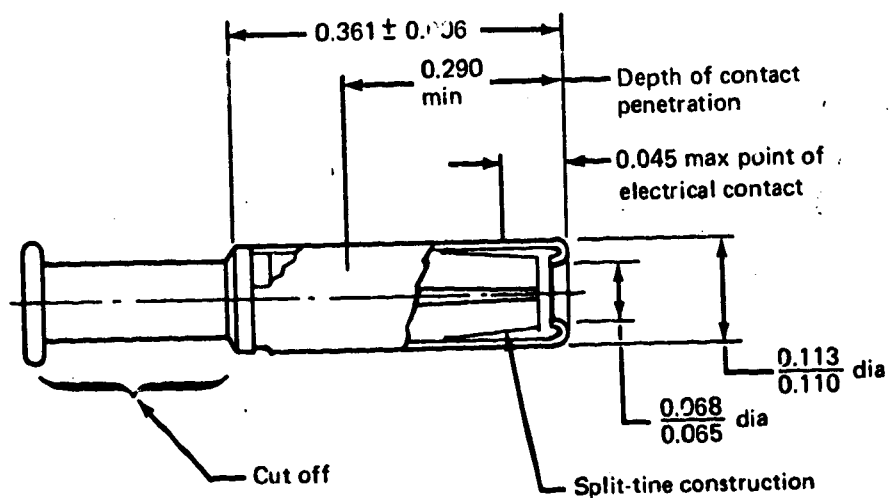
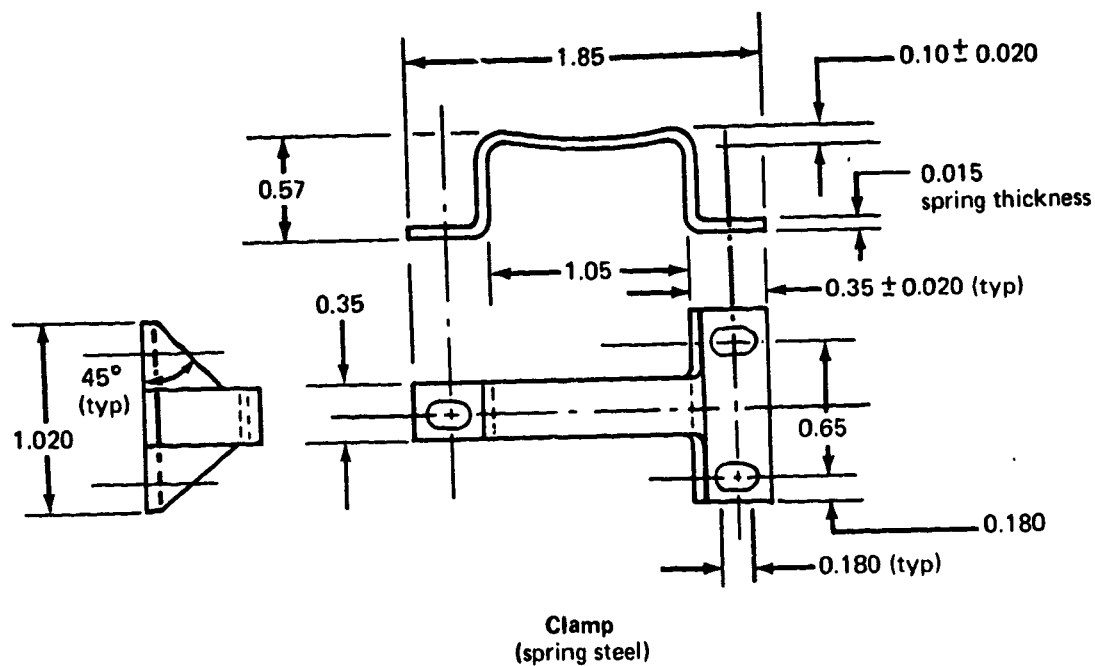
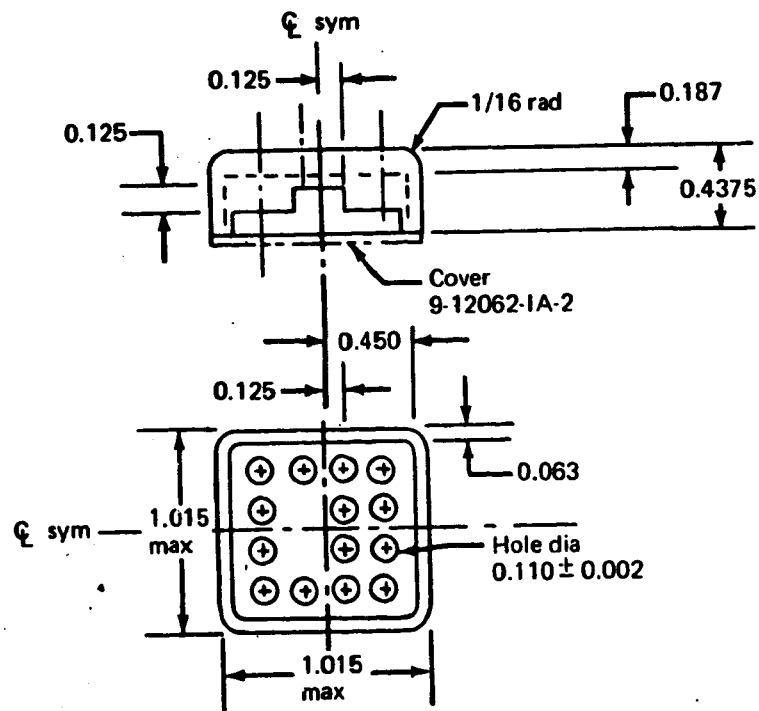


FIGURE 9.—LOW-PROFILE CONNECTOR INSTALLATION

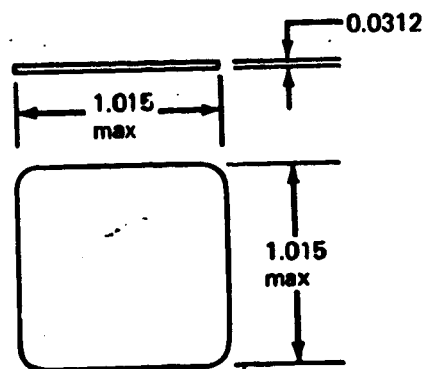


Electrical Contact Socket
(Viking Industries, Inc. 019-0249-000)

FIGURE 10.—LOW-PROFILE CONNECTOR COMPONENTS



Relay Connector Case



Relay Connector Cover

Case and cover of U.S. Polymerics'
diallyl phthalate/glass fiber
(PARR 1M20F per Mil-14F)
All dimensions in inches

FIGURE 10.—Concluded

- The socket lacks a flange to prevent socket push-back when mating with the relay.
- The longer socket necessitates a slightly higher unit so that the 3/8-in. design goal is exceeded by 1/16 in.

Problems

The problems associated with the fabrication of prototype samples are producibility problems, which are summarized as follows:

- The glass/silicone case material, being abrasive, was costly to machine.
- The modified socket contacts were ground to size and do not have a "flange" end so that a potential push-out problem exists.
- The pin locations in the relay were not accurate, so a jig to straighten the pins was required.

Processes

Full details of the processes involved to terminate and encapsulate the device are covered in the process specification, appendix A.

PERMANENT SPLICE

The design goal was to produce splice terminations that are electrically insulated to withstand the environmental conditions and are capable of being repaired and reworked on installed cables with the use of hand tools.

Concept 1 – Insulation-Piercing Crimp and "Box" Encapsulation

Design, Drawings, and Materials

This concept, described briefly under "Permanent FCC Transition Splices," is detailed in figures 11 through 14.

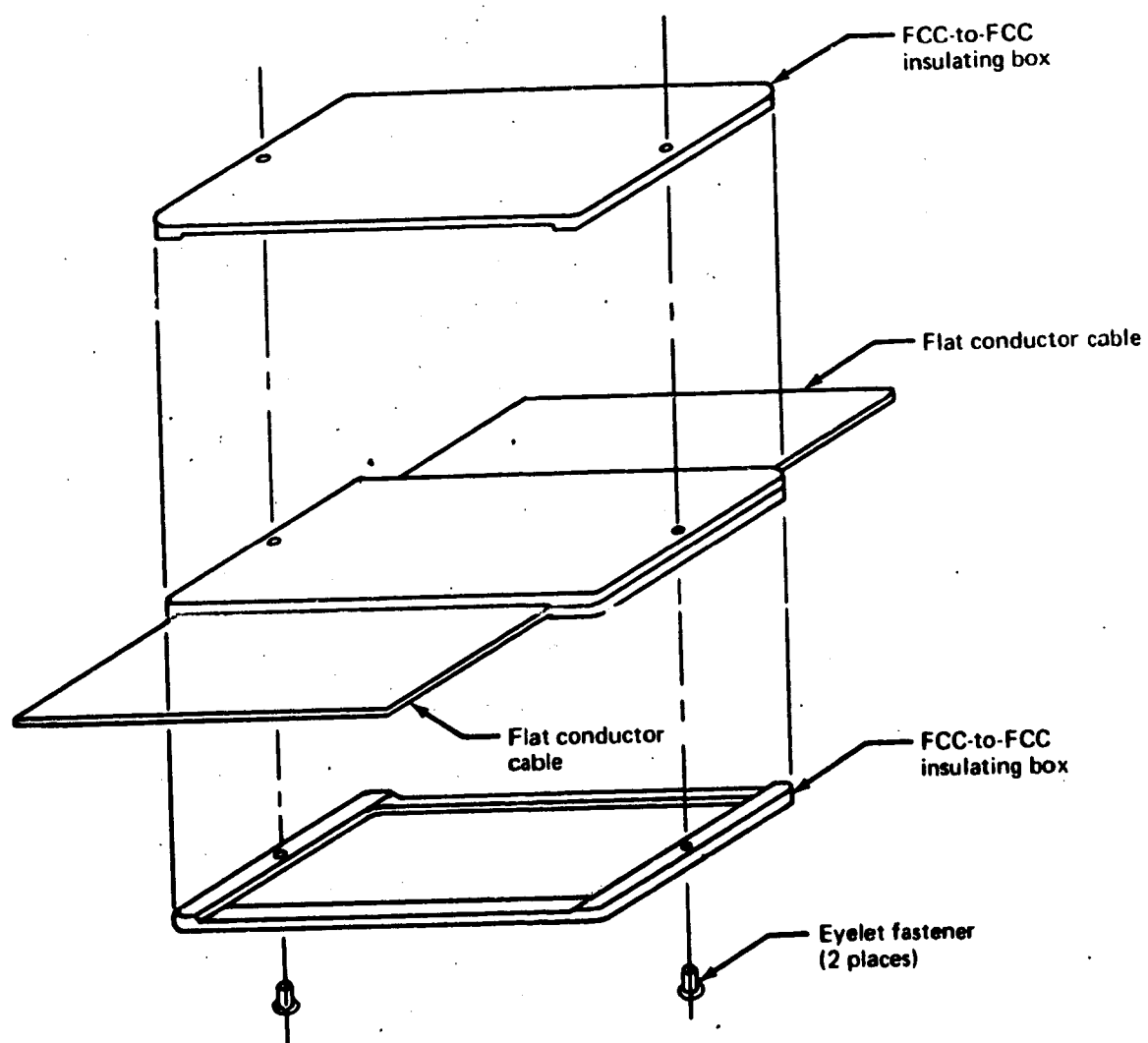


FIGURE 11.—EXPLODED VIEW OF COMPONENTS—FCC TO FCC

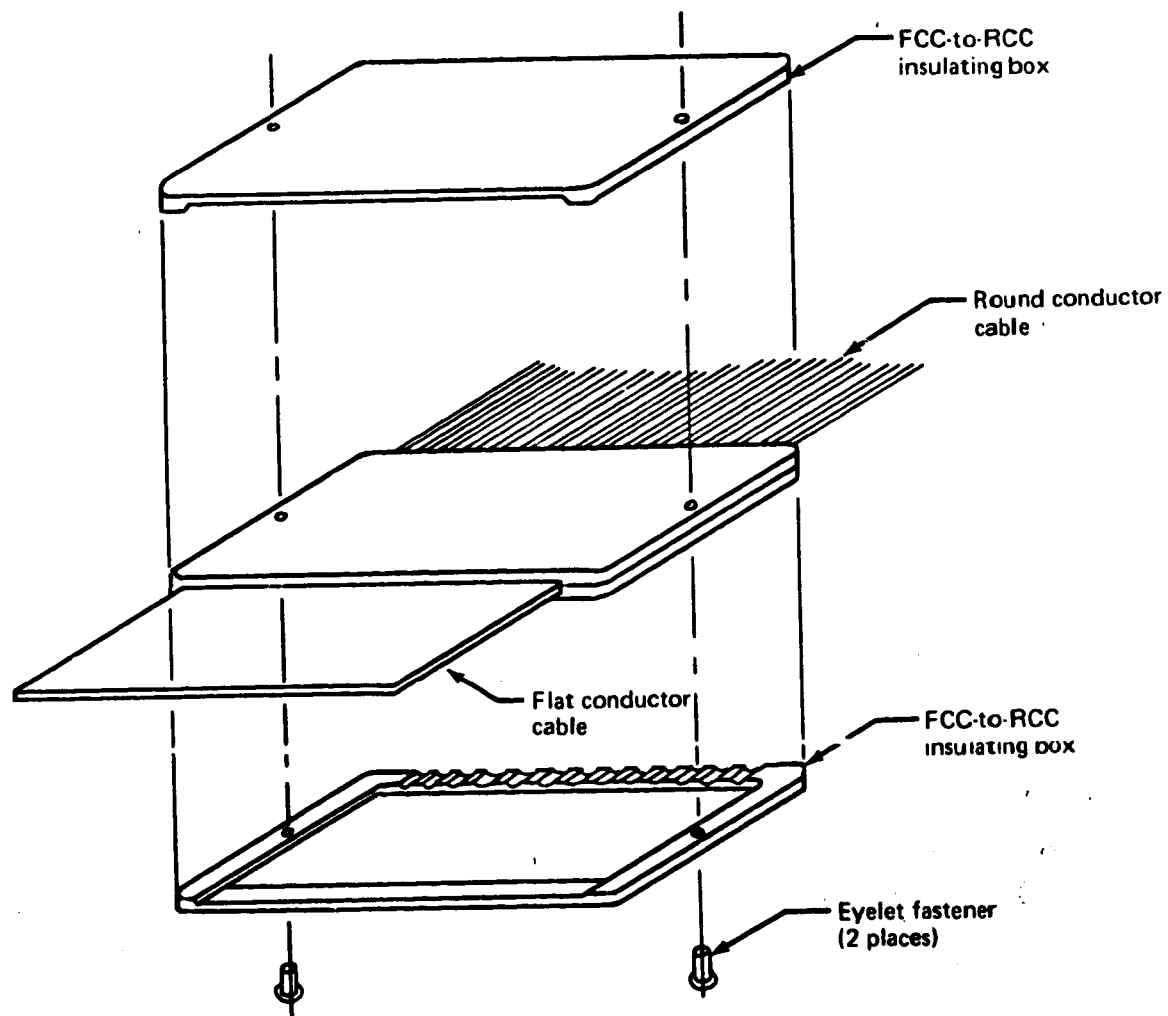
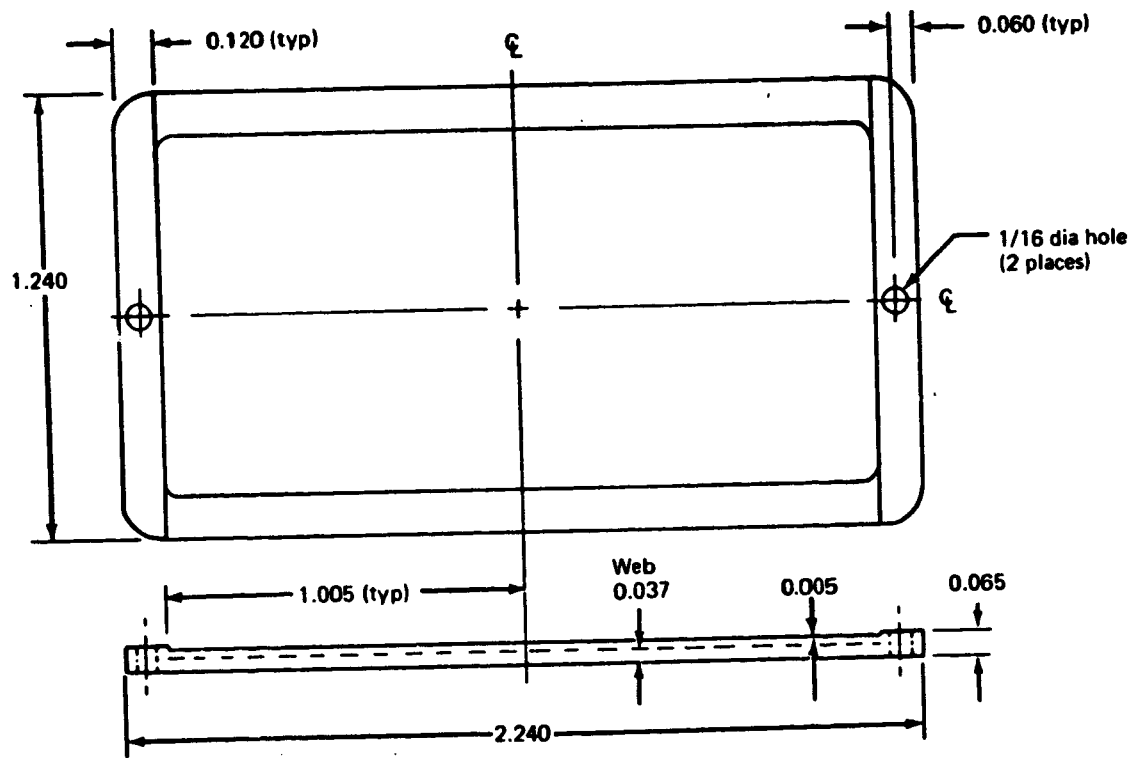
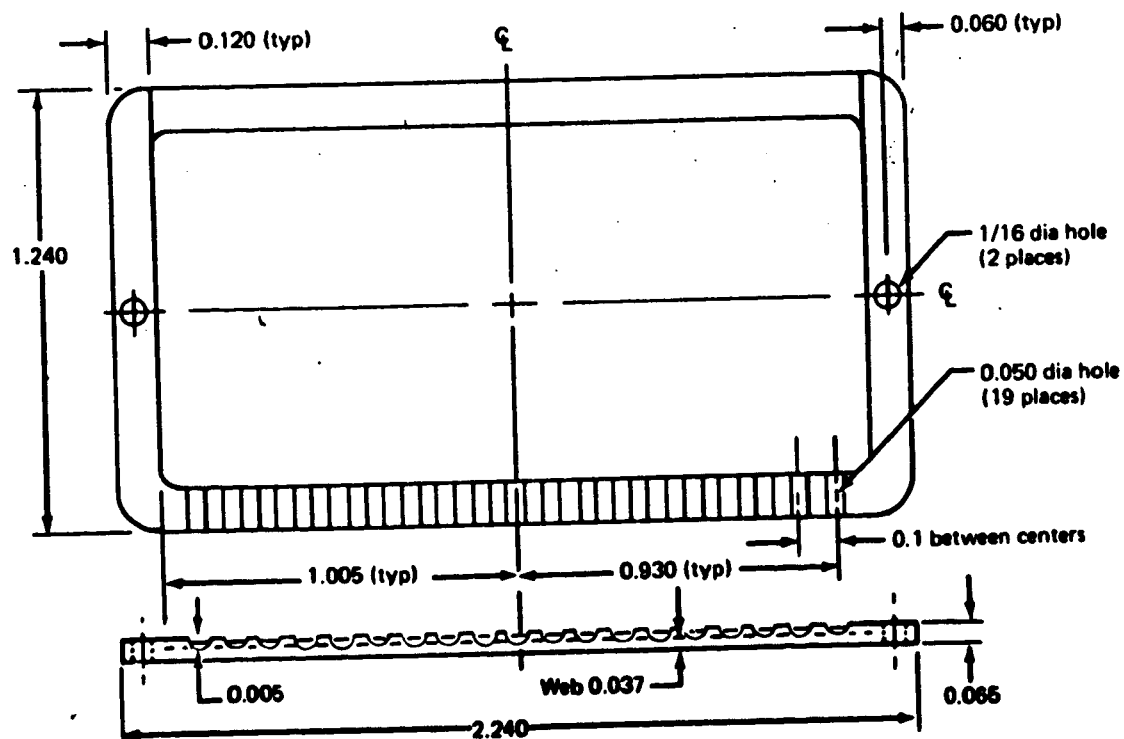


FIGURE 12.—EXPLODED VIEW OF COMPONENTS—FCC TO RCC



FCC-to-FCC Splice Box Half



Box halves of diallyl phthalate/glass fiber

All dimensions in inches

Tolerance: ± 0.002

FCC-to-RCC Splice Box Half

FIGURE 13.—BOX DETAILS—TRANSITION SPLICE

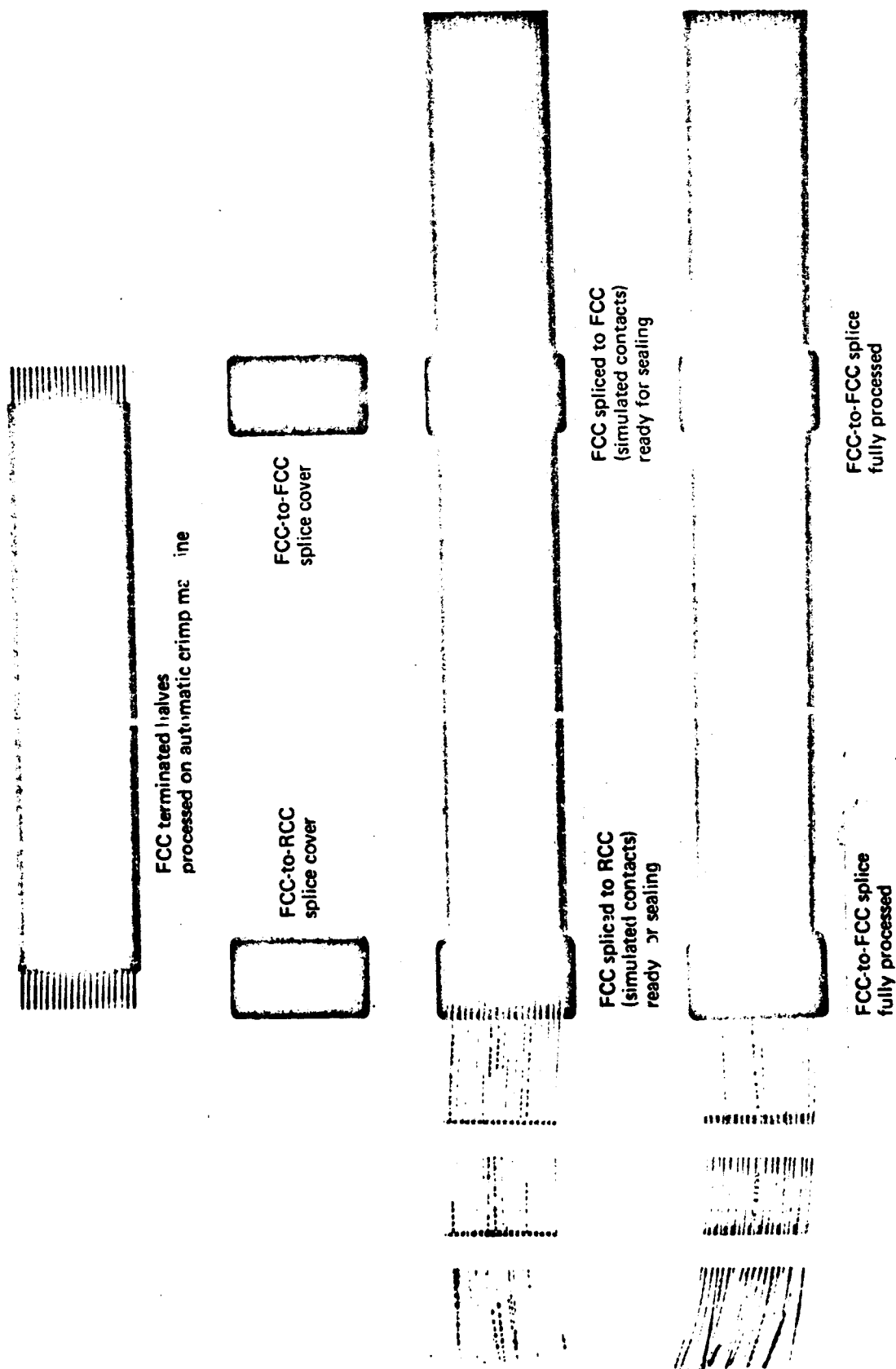


FIGURE 14.—COMPONENTS IN VARIOUS STAGES OF ASSEMBLY—FCC TO FCC AND FCC TO RCC

The design goal was met by the selection of the A-MP Unyt insulation crimp-through contact. To meet the requirements, an FCC-to-FCC "link" and an FCC-to-RCC "link" were required. The FCC bridge crimp was fabricated by using solder tabs cut and welded together to form the joining link (fig. 15). The FCC-to-RCC link was fabricated by using solder tabs (FCC side) and socket contacts (RCC side) and soldering the contacts as shown in figure 16.

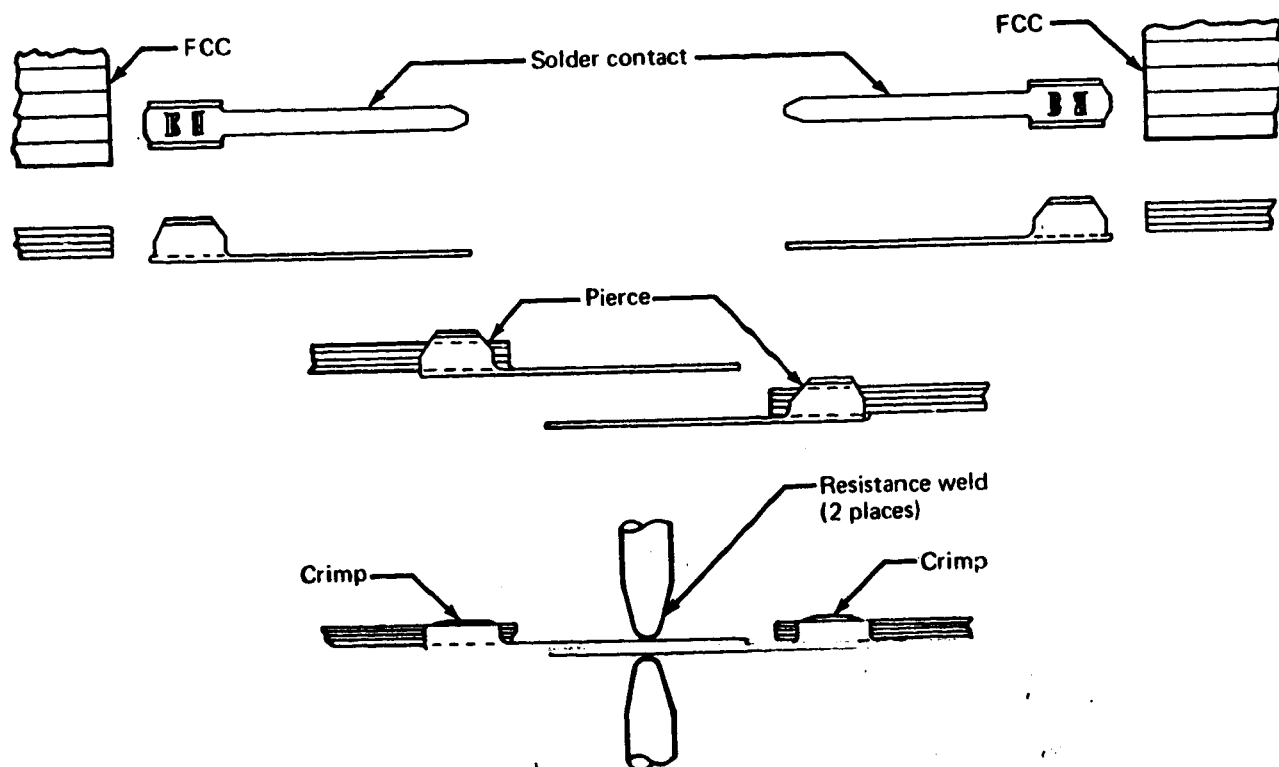


FIGURE 15.—TRANSITION SPLICE—FCC TO FCC

Crimping of the FCC contacts is economically and effectively carried out on the A-MP automatic FCC crimp machine (fig. 17). A prototype hand crimp tool is also available from A-MP (fig. 18).

The two box halves (fig. 13) designed to encase the terminations were molded in a single-cavity, steel, compression mold used in conjunction with a heated-platen hydraulic press. Press pressure was 2000 psi; mold temperature and time were 300°F and 1 min. Postcuring was at 400°F for 4 hr.

For the prototype, the mold was designed to have one slot for FCC entry on one side. For FCC-to-FCC splices, the FCC entry on the other side was machined. For FCC-to-RCC splices, holes were drilled on that side to form grooves for the round conductor. For the splice box, silicone/glass cloth was the preferred choice, but machining costs would be high if sheet stock were used and molding cost would also be high if B-stage glass cloth were used. Therefore, U. S. Polymeric, Inc. diallyl phthalate (IM20F type S06-4) was selected as the practical choice to prove the concept. This material has a

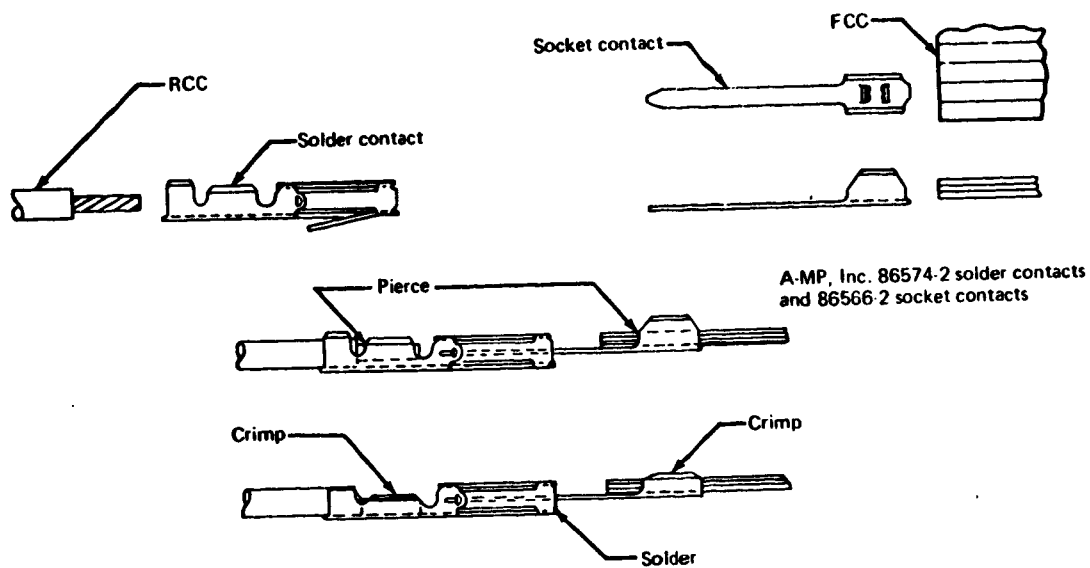


FIGURE 16.—TRANSITION SPLICE—FCC TO RCC



FIGURE 17.—A-MP AUTOMATIC CRIMP MACHINE



FIGURE 18.—A-MP FCC HAND CRIMP TOOL

satisfactory record in its application in connectors where good electrical properties at high temperature are required. The relative ease of molding this material justified the fabrication of a simple mold.

For repairs and branch circuit application, it is anticipated that these can be effectively carried out using the same concept but with box halves of adequate dimensions. Whether one splice or more is applied, a full-width box would be used for encapsulating the splice. Hardware was not developed for demonstration in this case.

Problems

The diallyl selected proved to be tough but brittle, but it was committed for production of test hardware. In an endeavor to provide data for future application, sample boxes were molded with diallyl having long glass fibers. This showed very slight improvement. However, parts molded with diallyl reinforced with glass cloth showed significant improvement but was projected to be costly.

Prototype boxes machined from Tefzel were obtained. These were tough and very flexible; however, bonding was a problem.

Investigations to obtain and test cost-effective box or case materials should be continued so that optimum characteristics are obtained.

The splice contacts used are longer than required; accordingly, the box length can be reduced significantly and a more compact arrangement obtained in the production splices.

Processes

A process specification covering the crimping and box insulation process is given in appendix B.

Concept 3—Multiple Termination Splice Module (MTSM)

Design, Drawings, and Materials

This concept, using the solder sleeve and heat-shrinkable sleeve, was introduced in "Permanent FCC Transition Splices." The heat-shrinkable sleeve was made from transparent, irradiated, cross-linked, heat-recoverable, polyvinylidene fluoride (Kynar) sheet bonded together and formed into a flat configuration to provide individual conductor cavities and a sheath at each end. Each cavity contained a preformed, soft ETP copper 110 interconnecting insert previously coated with a calculated amount of solder and flux. Each sheath was lined with a fusible material (Hytrel, a DuPont product), which melts and flows when heat is applied. Therefore, the sheath isolates and the Hytrel seals each individual soldered termination.

Details of this concept are in figures 19 through 23.

For a branch circuit or a repair splice, a single solder sleeve would be used. The details of this splice are clearly shown in figure 24.

Figures 25 and 26 show various branch circuits for FCC and RCC and also ribbon wire.

Problems

Failures with early test samples were caused by partial unbonding of the dielectric (Kynar) web between adjacent splices, pinholes in the MTSM jacket caused by misalignment of the heating tool, and sharp corners in the presolder splice insert. Meetings with Raychem Corp. over these failures brought about immediate response and favorable improvements in the design. The improvements are obtained from:

- A reduced width of metal insert (from 0.077 to 0.068 in.), which resulted in a wider and stronger bond and also gave more dielectric separation
- A reduced length of metal insert (from 0.50 to 0.40 in.) thereby increasing the end "tracking" distance.
- Rounded ends of metal inserts and all edges radiused so as to reduce sharp corners and field stresses and potential breakdown points
- Improved tooling that eliminated the misalignment problem and also improved the flow of material into the splice area.

Figure 27 compares the design changes.

In addition to the above, for the FCC-to-RCC splice, the metal insert with the spade end (for the FCC) or the barrel end (for the RCC) was reshaped at the transition point. The shoulder of the barrel was cut away to eliminate sharp corners and stress points and thinning out of the Kynar jacket during the heat-shrinking operation.

Processes

A process specification covering the application of the MTSM is given in appendix C. This includes illustrations of the special heating platens and other views.

The heating platen tool can be redesigned to make the transition joints in a fueled vehicle.

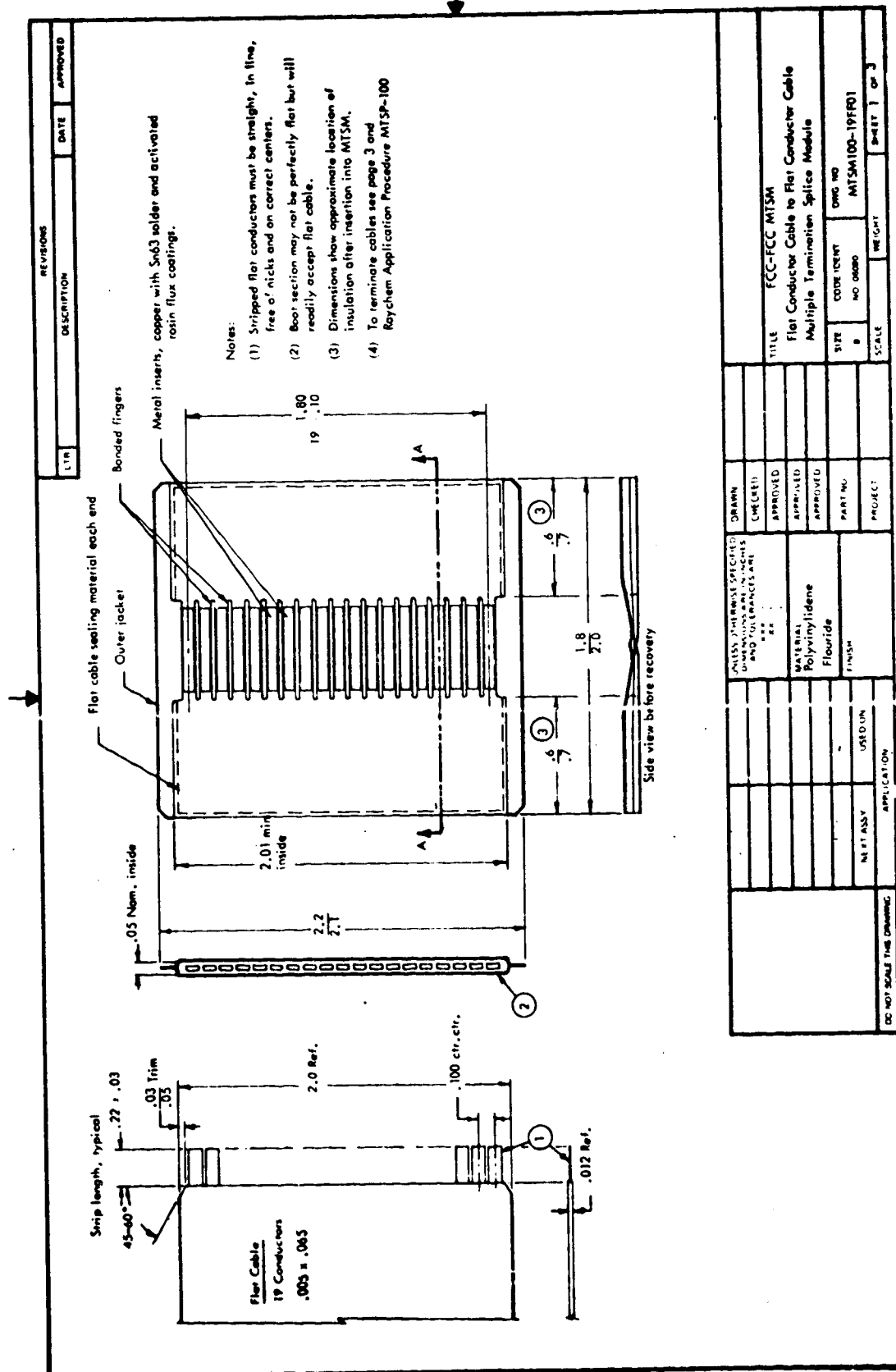


FIGURE 19.—FCC-TO-FCC MODULE (RAYCHEM DRAWING)

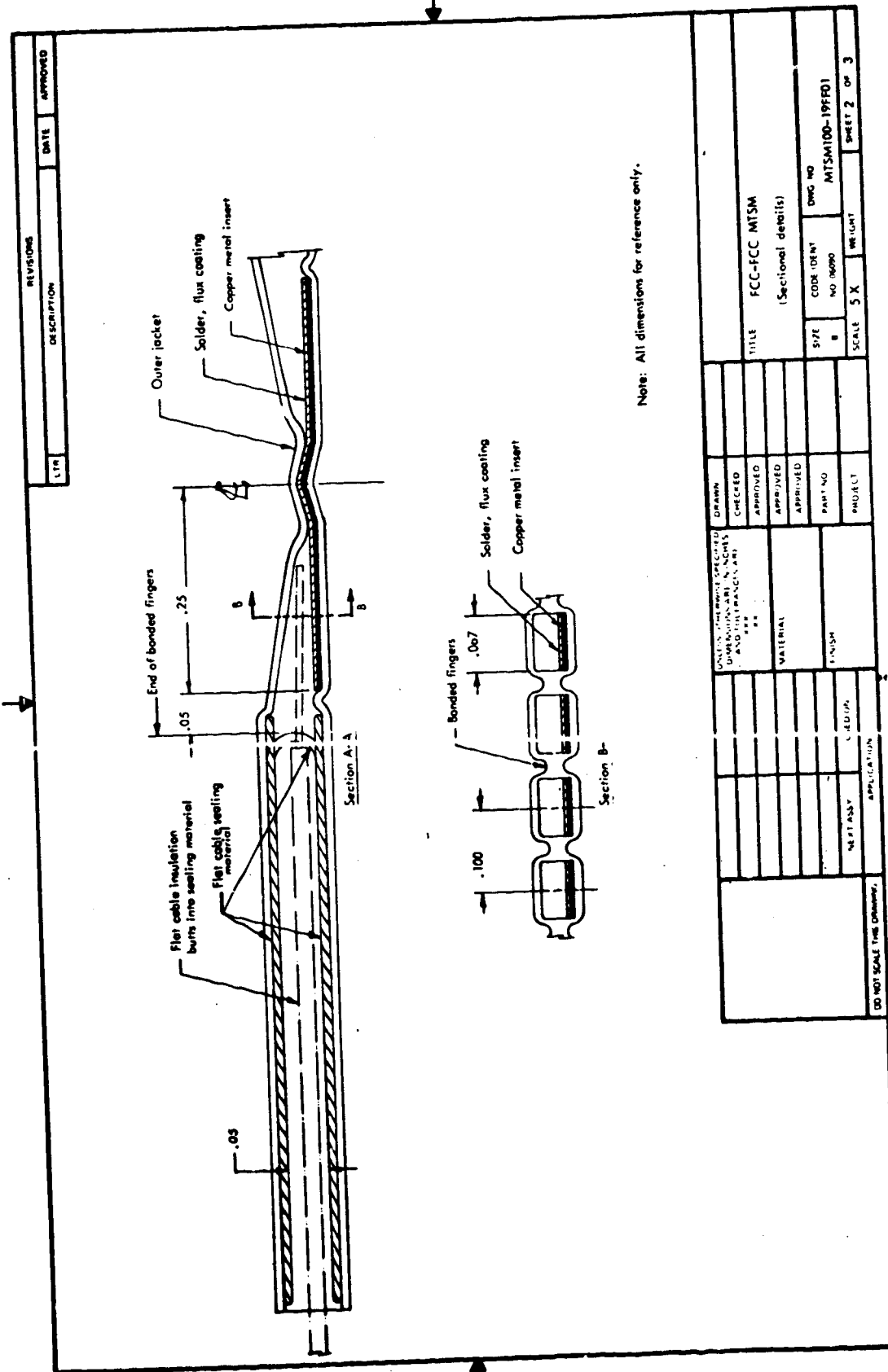


FIGURE 20.-FCC-TO-FCC MODULE SECTIONAL DETAILS (RAYCHEM DRAWING)

REPRODUCIBILITY OF THE ORIGINAL PART IS POOR.

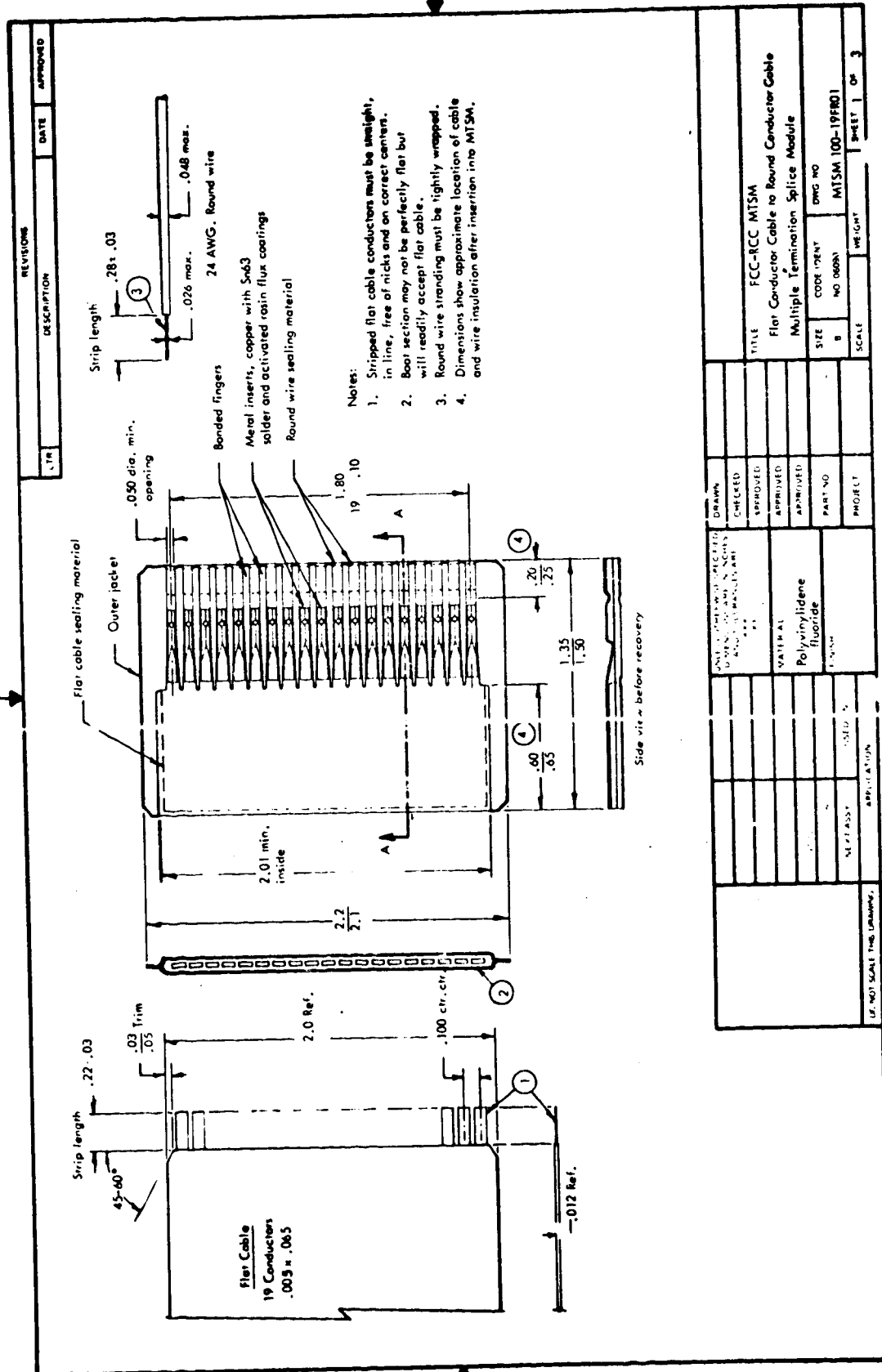
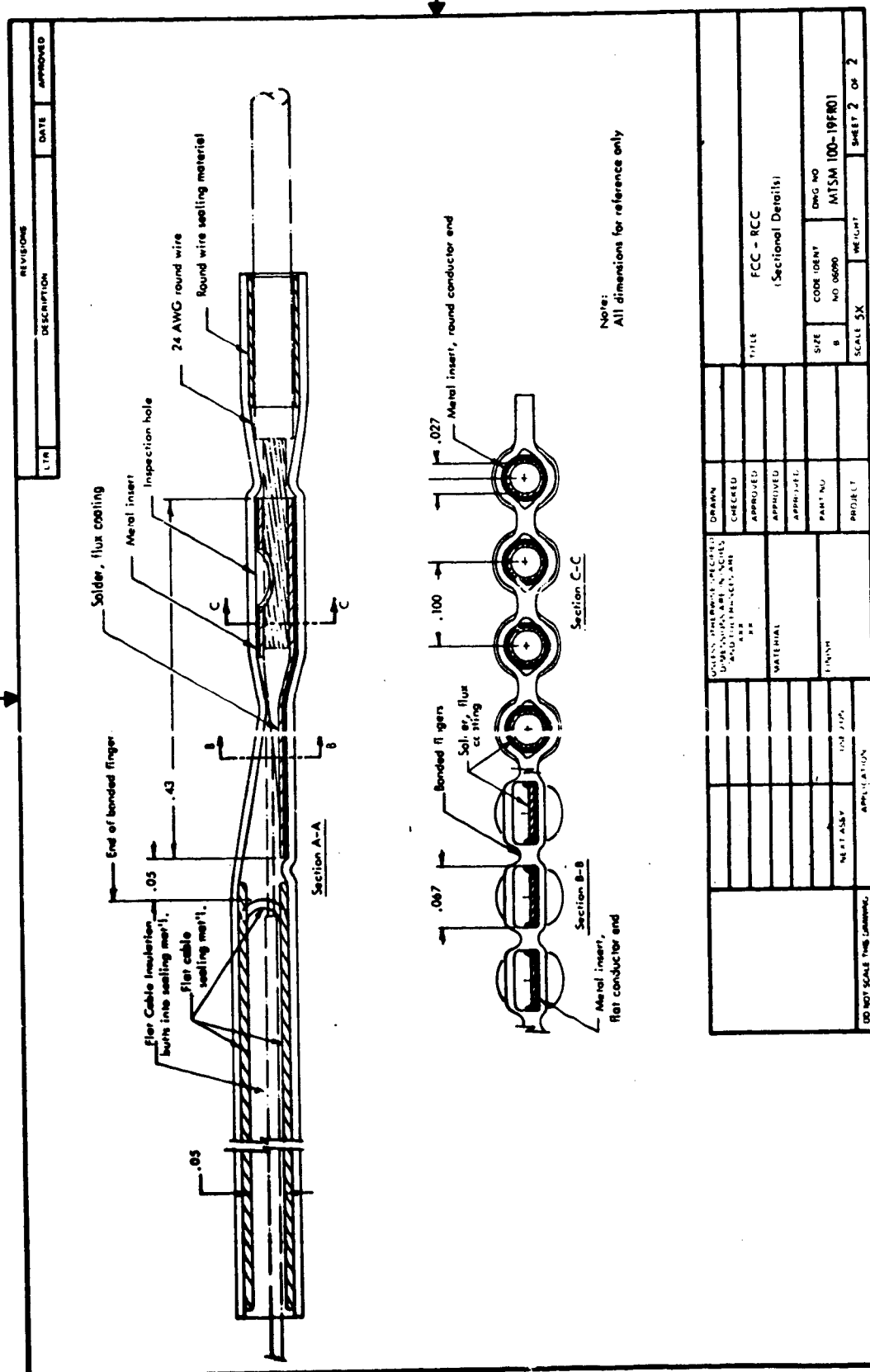
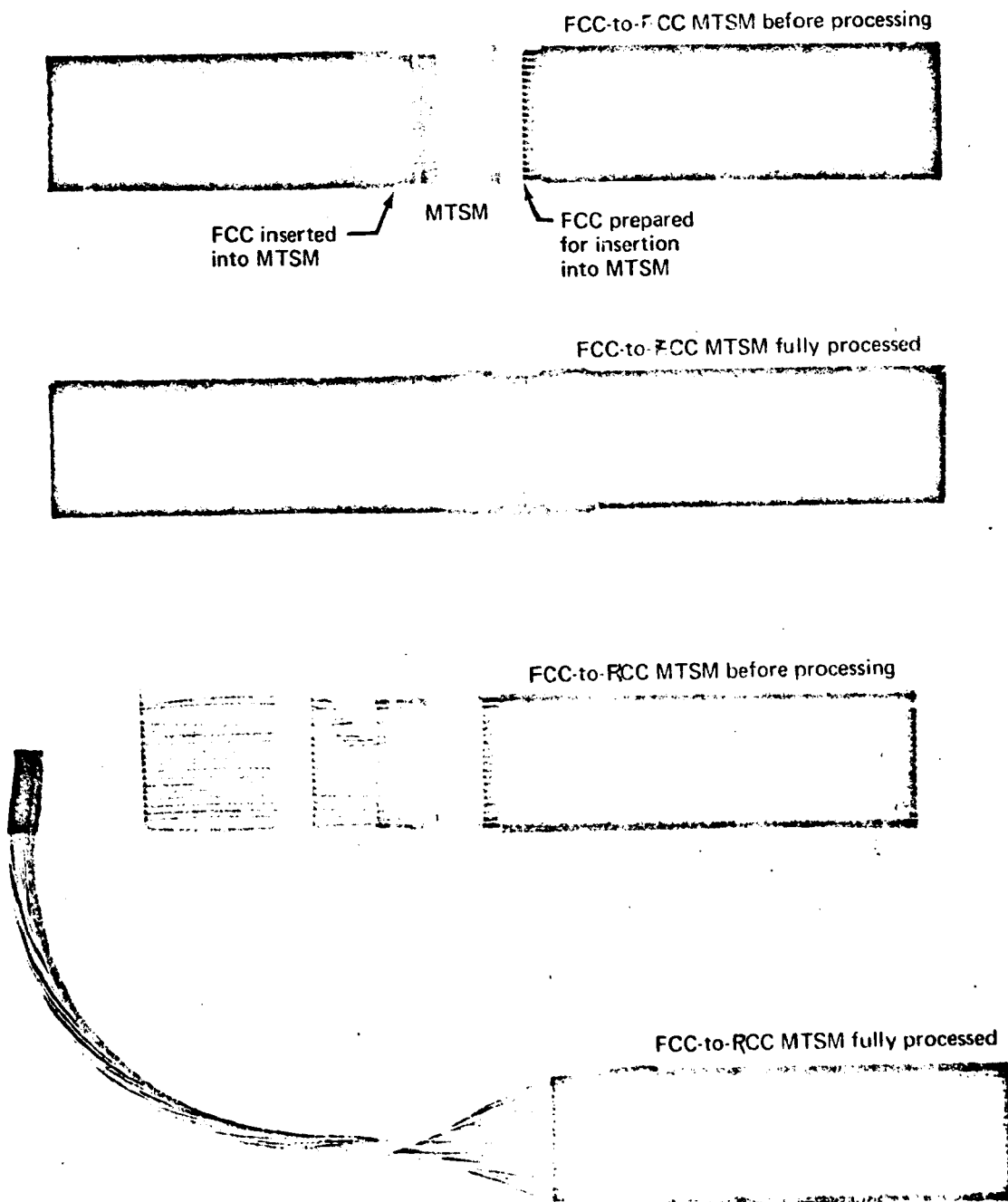


FIGURE 21.-FCC-TO-RCC MODULE (RAYCHEM DRAWING)





**FIGURE 23.—COMPONENTS IN VARIOUS STAGES OF ASSEMBLY—
FCC TO FCC AND FCC TO RCC**

- ① Insulation sleeve
Heat shrinkable, radiation cross-linked, modified polyvinylidene fluoride, transparent blue.
- ② Flux-filled solder preform
Sn 63 RAP 2 per Federal Specification QQ-S-571.
- ③ Sealing rings
Modified thermoplastic.
- ④ Buss bar
Copper alloy coated with Sn 63 alloy and noncorrosive activated flux.

Notes:

This part is designed for use with FCC having 0.065-in.-wide conductors on 0.100-in. centers such as M55543/19-H4E19. It may be used to splice the individual conductors or to make breakouts to individual wires or flat cables having either round conductors (24 gage max) or flat conductors (0.065-in. wide max).

Acceptance sampling shall be in accordance with MIL-STD-105. The acceptable quality level (AQL) shall be 4.0.

The FCC must be prepared by slitting the conductor to be spliced and adding the branch circuit. The transition is processed by the application of heat.

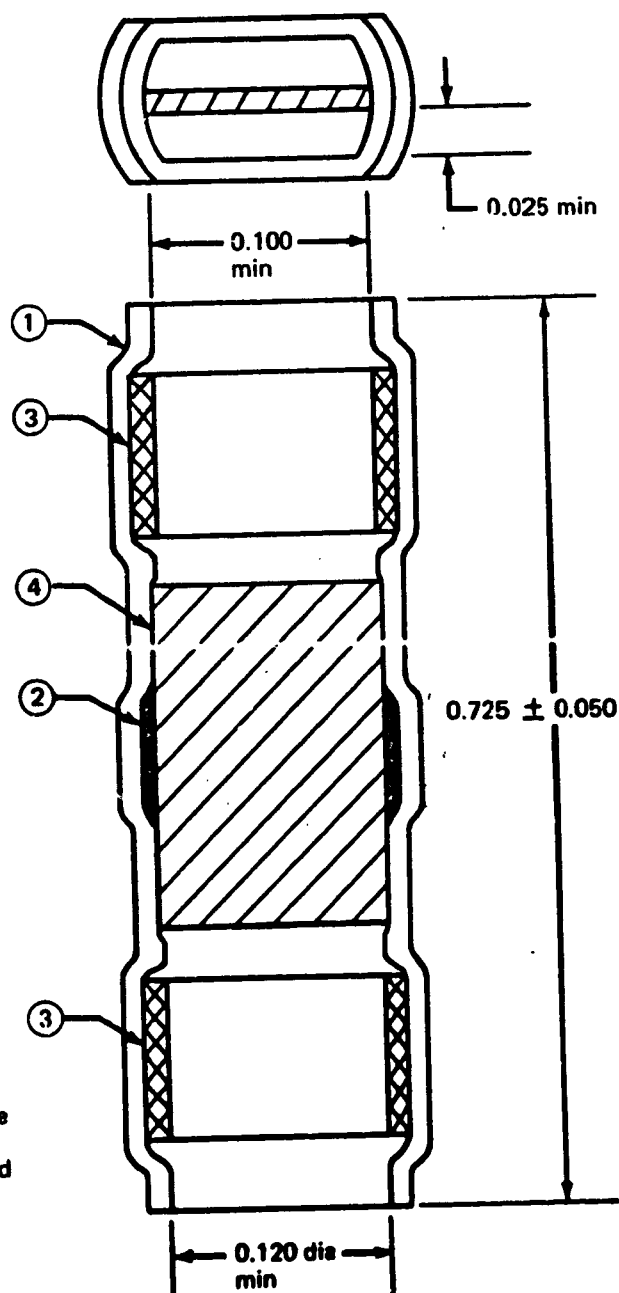


FIGURE 24.—SINGLE-CIRCUIT SPLICE

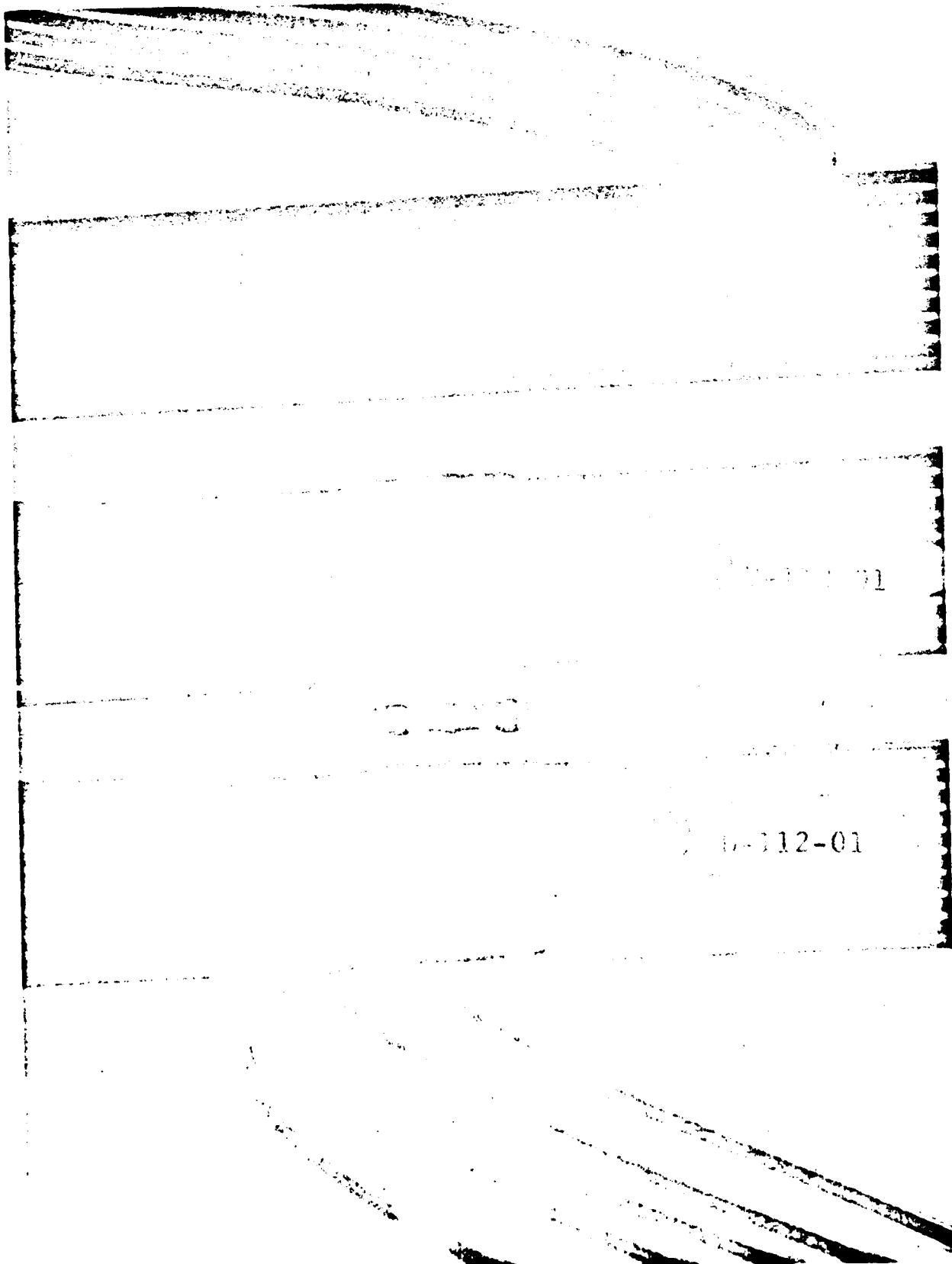


FIGURE 25.—SPLICE-BRANCH CIRCUIT TO FCC

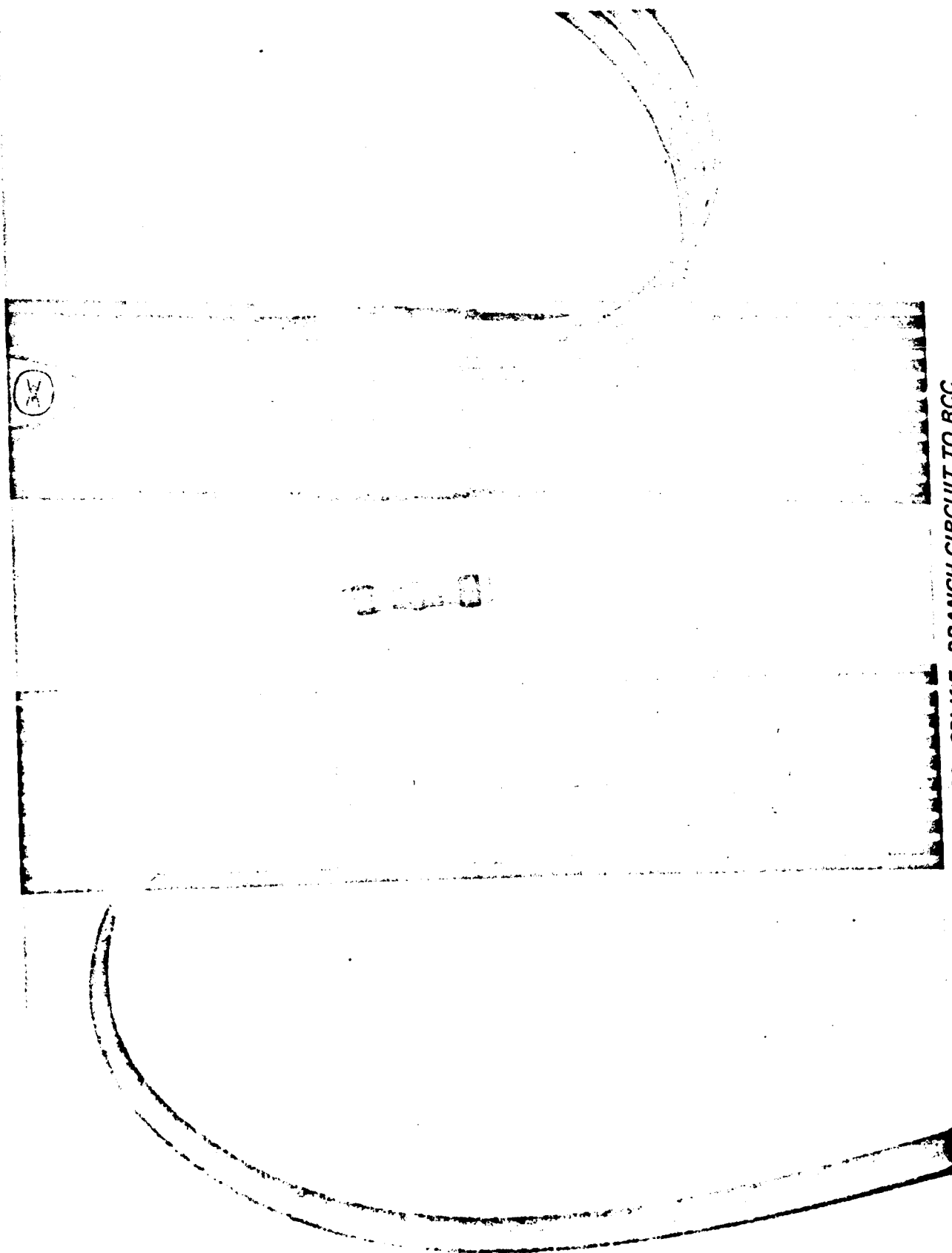
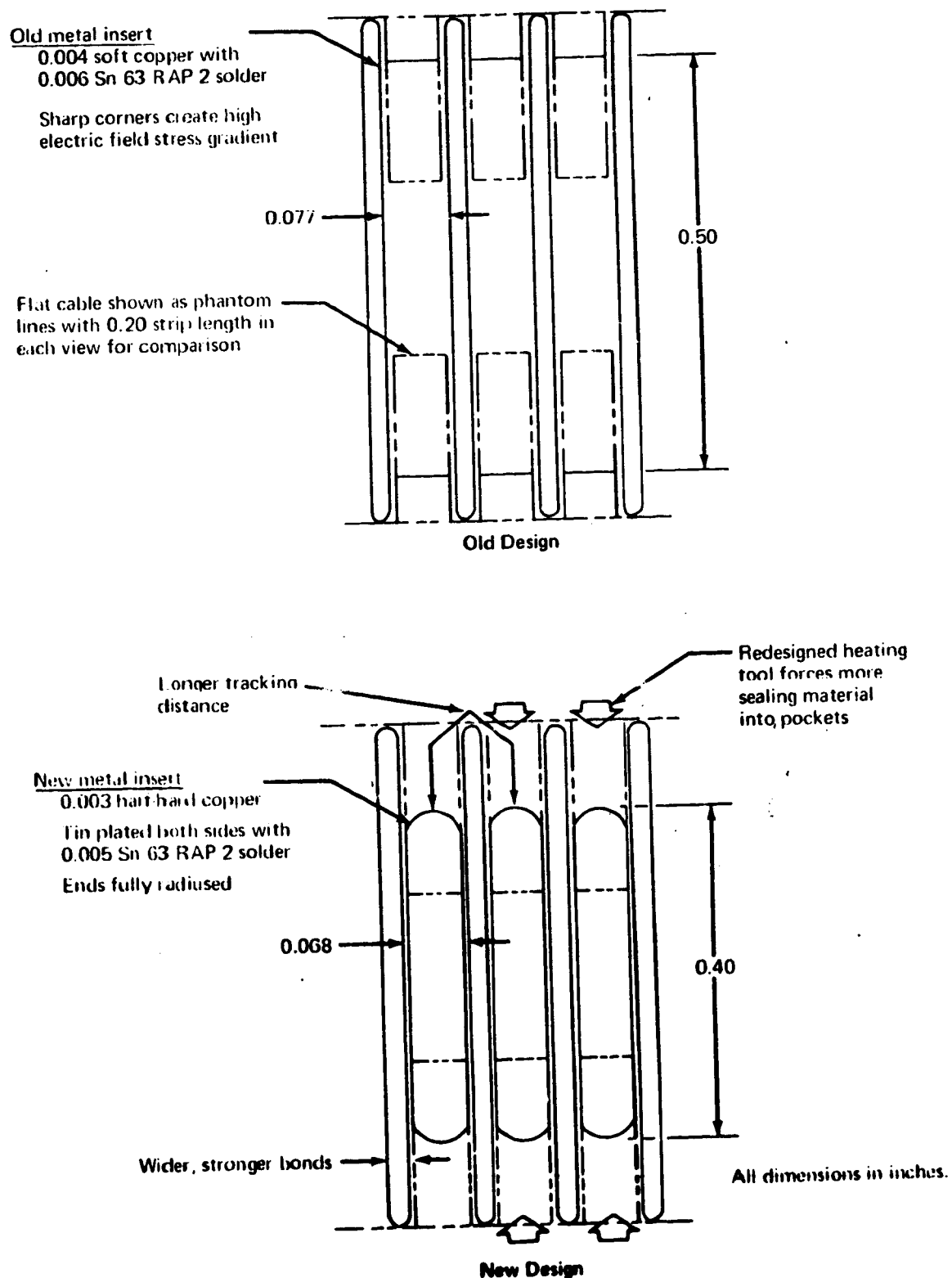


FIGURE 26. - SPLICE-BRANCH CIRCUIT TO RCC



**FIGURE 27. - IMPROVEMENTS TO MTSM DESIGN
 (PARTIAL PLAN VIEWS OF SPLICE AREA 5X FULL SCALE)**

TEST PROGRAM AND DATA ANALYSIS

DISCUSSION OF TEST PROGRAM

A single test plan was developed for both the low-profile connecting devices and the permanent splices. The plan with test procedures, requirements, and instrumentation is included as appendix D.

The various electrical and environmental tests outlined in appendix D were selected to produce sufficient data to evaluate the performance of the selected materials and splice methods. The electrical performance of the junction was verified by monitoring electrical continuity and millivolt drop (MVD) before and after exposure to each environment. The environmental sealing and insulation material integrity were verified by insulation resistance and dielectric withstand tests initially and after each environmental exposure. The intensity and level of testing were based on the requirements for use in manned space vehicles. Military standards and NASA-MSC Apollo environment were used where applicable.

In the case of permanent splices, MVD instrumentation leads were incorporated internal to the splices to avoid initial damage and subsequent degradation of the encapsulation system. The techniques and MVD procedure are also detailed in appendix D.

The vibration test on permanent splices was waived by agreement with the contract monitor after test results of a previous test were submitted, discussed, and accepted by similarity. It was also agreed that the current-temperature life test was not required for completion of the test sequence, but it would be advisable to perform this test as a follow-on effort.

In regard to flammability testing (in 100% oxygen, 5 psia atmosphere) of insulation and bonding materials used in the fabrication of the permanent splices, a detailed test procedure was submitted to NASA and approved. However, it was later agreed that such a test would not be required. An assessment of material flammability based on NASA requirements and published test data on similar materials would be sufficient. Two references were consulted and used in this regard:

- *Nonmetallic Materials Design Guidelines and Test Data Handbook*, Manned Spacecraft Center, Houston, Texas, January 15, 1971
- *Procedures and Flammability, Odor, and Outgassing Requirements and Test Procedures for Materials in Environments That Support Combustion*, Manned Spacecraft Center, Houston, Texas, July 1968.

TEST DATA

Low-Profile Connecting Device Test Data

Eight connecting devices were terminated to 2 ft of FCC and mated to functional relays. Two mounting fixtures were designed and fabricated (see fig. 28). Samples were mounted on the fixtures and tested in accordance with the test procedures and test sequence of appendix D.

To test all contacts, the relay coil was energized with rated 28 Vdc to close or open relay contacts as required by the test being performed.

It is noteworthy to mention that, during the vibration test, the test equipment momentarily experienced an abnormality that resulted in a vibration input level to the test samples three times the level specified in the test. Postvibration tests revealed no failure or damage to the connecting devices. Figure 29 is a photo record of the vibration test instrumentation.

The electrical performance of the connecting devices was verified by measuring the millivolt drop change after each environment. Table 10 records the test results.

The sealing capability and insulation integrity of the potting material were checked by insulation resistance and dielectric withstand voltage tests. Table 11 summarizes the test results.

Permanent Splice Test Data

Twenty test samples each—10 FCC to FCC and 10 FCC to RCC—of the "box" concept (concept 1) and the multiple termination splice module (MTSM) concept (concept 3) were tested in accordance with the test procedures and test sequence contained in appendix D.

A-MP Crimp "Box" Concept 1 Test Data

All 20 samples were instrumented with jumpers to monitor four conductors of each splice. Test results of electrical continuity and MVD measurements of the three samples subjected to the complete environment sequence (B2, B3, B4) are recorded in table 12. A graphic representation of these values is plotted in figure 30. The MVD of an equal length of unspliced FCC is also included for comparison.

Dielectric withstand and insulation resistance test data with failure details are summarized in table 13.

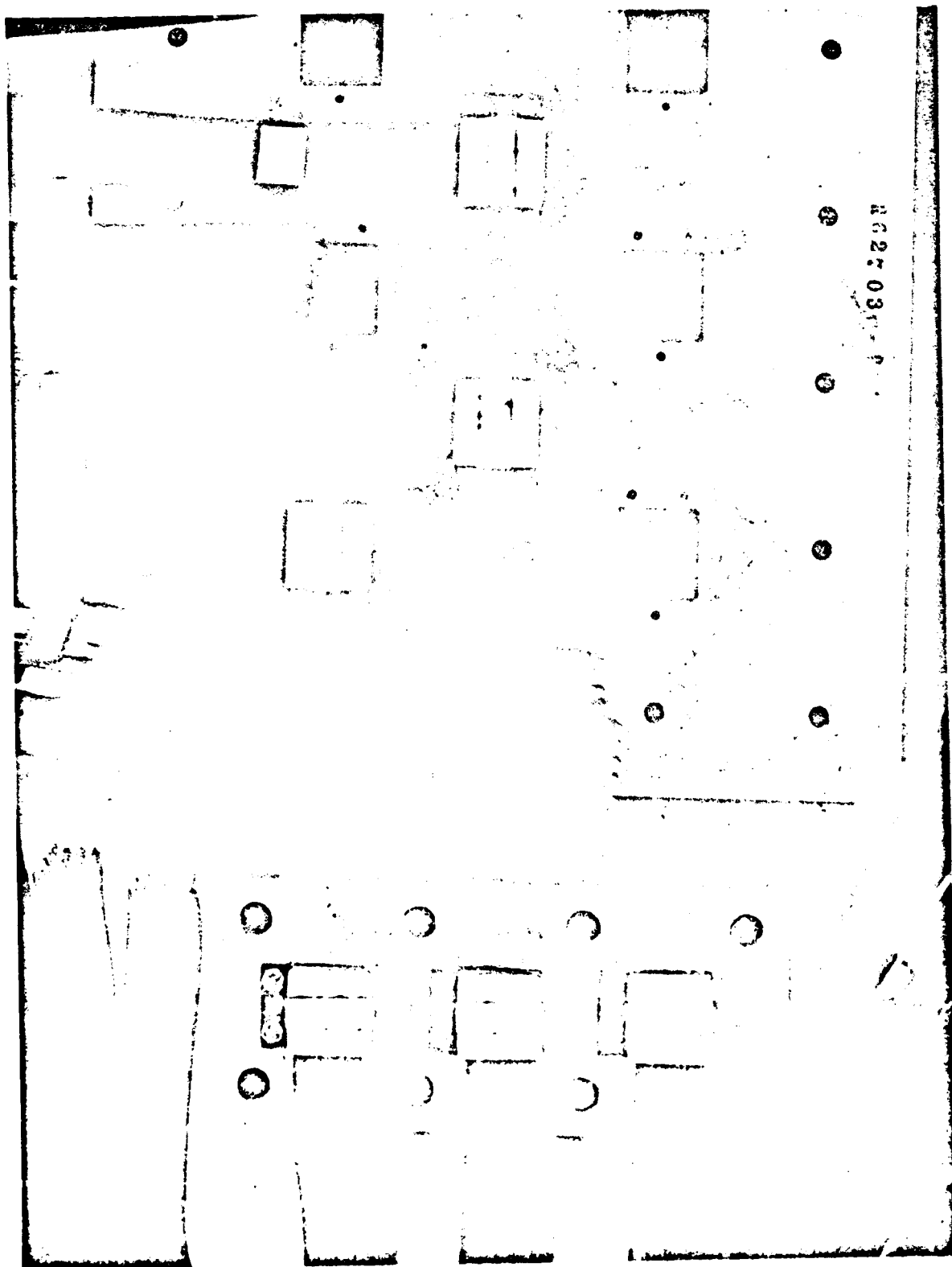


FIGURE 28.-LOW-PROFILE CONNECTING DEVICE MOUNTING FIXTURES

TABLE 10.-LOW-PROFILE CONNECTING DEVICE TO RELAY MVD CHANGE WITH ENVIRONMENT

Sample code	Relay mode ^a	MVD change with environment ^b						Change, %
		Initial test	After thermal shock	After thermal aging	After vibration	After moisture	After salt fog	
D1	NO	248	252	261	—	270	270	8.9
	NC	248	226	264	—	274	268	8.0
D2	NO	256	259	287	279	282	358	40.0
	NC	258	262	275	270	274	282	9.3
D3	NO	254	257	260	255	266	265	4.3
	NC	253	254	261	260	265	269	6.3
D4	NO	253	257	322	275	314	314	24.0
	NC	251	255	261	270	283	280	11.3
D5	NO	252	253	299	—	302	308	22.0
	NC	261	260	301	—	305	311	15.9
D6	NO	256	257	280	—	292	353	38.0
	NC	260	260	288	—	299	291	12.0
D7	NO	259	257	—	—	—	—	—
	NC	260	258	—	—	—	—	—
D8	NO	252	251	—	—	—	—	—
	NC	251	250	—	—	—	—	—

^aNO = normally open-28 Vdc applied to close contacts for MVD testing.

NC = normally closed.

^bAverage of four contact circuit measurements at 5 amp.



FIGURE 29.—LOW-PROFILE CONNECTING DEVICES UNDER VIBRATION TESTING

TABLE 11.—INSULATION RESISTANCE AND DIELECTRIC WITHSTAND VOLTAGE TEST DATA

Sample code	Relay mode ^a	Insulation resistance and dielectric withstand voltage											
		Initial test		After thermal shock		After thermal aging		After vibration		After moisture		After salt fog	
		IR	DWV	IR	DWV	IR	DWV	IR	DWV	IR	DWV	IR	DWV
D1	NO	OK	OK	OK	OK	OK	OK	—	—	OK	OK	OK	OK
	NC	OK	OK	OK	OK	OK	OK	—	—	OK	OK	OK	OK
D2	NO	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	Fail	OK
	NC	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	Fail	OK
D3	NO	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	Fail	Fail
	NC	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	Fail	Fail
D4	NO	OK	OK	OK	OK	OK	OK	OK	OK	Fail	OK	Fail	OK
	NC	OK	OK	OK	OK	OK	OK	OK	OK	Fail	Fail	Fail	Fail
D5	NO	OK	OK	OK	OK	OK	OK	—	—	Fail	OK	Fail	Fail
	NC	OK	OK	OK	OK	OK	OK	—	—	Fail	Fail	Fail	Fail
D6	NO	OK	OK	OK	OK	OK	OK	—	—	OK	OK	OK	OK
	NC	OK	OK	OK	OK	OK	OK	—	—	OK	OK	OK	OK
D7	NO	OK	OK	OK	OK	—	—	—	—	—	—	—	—
	NC	OK	OK	OK	OK	—	—	—	—	—	—	—	—
D8	NO	OK	OK	OK	OK	—	—	—	—	—	—	—	—
	NC	OK	OK	OK	OK	—	—	—	—	—	—	—	—

^aNO = normally open—28 Vdc applied to close contacts for testing.

NC = normally closed.

TABLE 12.-A-MP CRIMP CONCEPT PERMANENT SPICE TERMINATION MVD CHANGE WITH ENVIRONMENT

TABLE 12.—A-MP CRIMP CONCEPT PERMANENT SPICE TERMINATION IN VOLTAGE															
Sample code and conductor number	Electrical continuity		Splice voltage drop, mV								Current cycling, ^b hr			Equal lengths of FCC	
	Through- spliced conductor	Jumped conductors for MVD	Initial test	After thermal shock	After thermal aging	After vibration ^a	After moisture	After salt fog	50			100			150
B2-2	OK	OK	21.17	18.92	8.89		19.43	19.55						6.04	
B2-3	OK	OK	13.27	13.40	3.50		13.56	13.48						6.04	
B2-12	OK	OK	14.02		4.41		14.83	14.77						6.04	
B2-13	OK	OK	14.16	14.19	4.41		14.43	14.43						6.04	
B3-2	OK	OK	22.82	24.84	8.27		28.61	28.61						6.04	
B3-3	OK	OK	15.75	15.94	6.09		16.10	16.00						6.04	
B3-12	OK	OK	14.34	14.25	4.29		14.31	14.28						6.04	
B3-13	OK	OK	14.47	14.88	5.01		15.08	15.04						6.04	
B4-2	OK	OK	12.90	13.11	3.20		13.20	13.22						6.04	
B4-3	OK	OK	13.13	13.39	3.34		13.42	13.44						6.04	
B4-12	OK	OK	14.11	14.17	14.11		14.17	14.15						6.04	
B4-13	OK	OK	13.10	13.23	13.27		13.23	13.24						6.04	

^aNot required, accepted by similarity.

^bTest weaved by agreement with technical monitor.

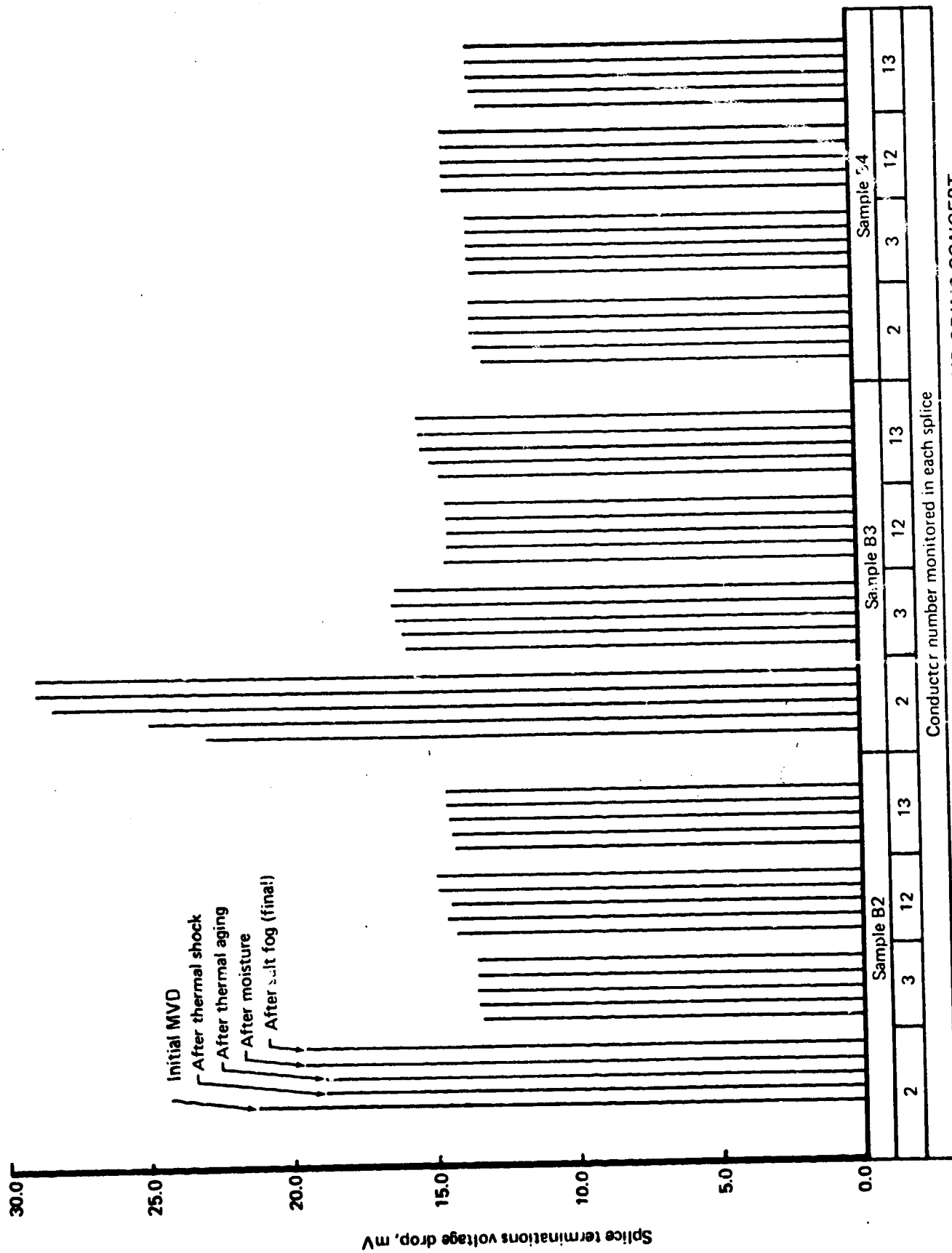


FIGURE 30.—FCC-TO-FCC SPLICES INSTRUMENTED FOR MVD—A-MP CRIMP CONCEPT

TABLE 13.-A-MP CRIMP CONCEPT PERMANENT SPLICE INSULATION RESISTANCE
AND DIELECTRIC WITHSTAND VOLTAGE TEST DATA SUMMARY

Sample code ^a	Insulation resistance and dielectric withstand voltage					Failure details			
	Initial test	After thermal shock	After thermal aging	After moisture	After salt fog (final)	Failed conductors	Location (conductor no.)	Type	Voltage, min
B1	OK	OK	N/R	N/R	N/R	None	-	-	-
B2	OK	OK	OK	OK	OK	None	-	-	-
B3	OK	OK	OK	OK	Fail	2	16, 17	Leak to adjacent	12
B4	OK	OK	OK	OK	Fail	11	4, 5, 6, 7, 8, 9, 10, 12, 13, 18, 19	IR < 500 V	500
B5	OK	OK	OK	OK	Fail	2	12, 13	Leak to adjacent	10
B6	OK	OK	N/R	OK	Fail	10	2, 3, 6, 7, 8, 14, 15, 16, 17, 18	IR to adjacent	500
B7	OK	OK	OK	N/R	N/R	None	-	-	-
B8	OK	OK	N/R	Fail	Fail	6	7, 8, 9, 10, 14, 15	Leak and IR to adjacent	10
B9	Fail	Fail	N/R	N/R	N/R	2	10, 11	Leak to adjacent	10
B10	OK	OK	N/R	N/R	N/R	None	-	-	-
B21	OK	OK	N/R	N/R	N/R	None	-	-	-
B22	OK	OK	OK	Fail	Fail	1	8	Leak to solution and IR to adjacent	10
B23	OK	OK	OK	OK	OK	None	-	-	-
B24	OK	OK	OK	OK	OK	2	12, 13	Shorts	-
B25	OK	OK	Fail	Fail	Fail	17	All except 17, 18	Dielectric breakdown and IR	10
B26	OK	OK	N/R	OK	OK	None	-	-	-
B27	OK	Fail	Fail	N/R	N/R	4	2, 3, 4, 5	Leak to adjacent	10
B28	OK	OK	N/R	OK	OK	None	-	-	-
B29	OK	OK	N/R	N/R	N/R	None	-	-	-
B30	OK	OK	N/R	N/R	N/R	None	-	-	-

^aAll samples were instrumented for MVD (2, 3, 12, and 13 monitored; 1, 4, 11, and 14 used as sensing leads).

MTSM Test Data

Two generations of samples were tested. After conducting initial tests on the first generation and experiencing failures of dielectric and insulation resistance, problems were identified and corrective measures taken. Table 14 summarizes the test results. Problem details and measures taken to correct them are covered earlier in the fabrication discussion of the MTSM concept. All first-generation samples were delivered to Raychem and were not considered for any further testing.

A second generation of test samples with improved design was made available for further testing. Therefore, all test results and analyses that follow are in relation to the second generation of samples.

Three FCC-to-FCC samples (A2, A3, A4) were instrumented internally to monitor four of the 19 conductor junctions for MVD changes. Test results of electrical continuity and MVD after each environment are recorded in table 15. For comparison, the MVD of an equal length of FCC was measured and recorded. Figure 31 is a graphic representation of the MVD values appearing in table 15.

A summary of the dielectric withstand voltage and insulation resistance test results on all 20 samples appear in table 16.

TEST DATA ANALYSIS

A reliable electrical junction has a consistent and stable MVD when subjected to the environment. To determine whether the insulating materials and spacing of conductors in a splice or device are adequate, a dielectric withstand voltage test is performed after each environment. The insulation resistance measurements indicate the extent of insulating material deterioration and the change in properties due to the influence of environment.

Low-Profile Connecting Device Data Analysis

The low-profile connecting device and its mating relay were tested for operation and electrical characteristics. The MVD data appearing in table 10 consist of the total circuit drop including the FCC test leads, the soldered socket, the device socket to mating relay pin, and the relay contacts. The relay contacts were cycled 100 times (coil energized and de-energized) to eliminate contact surface peculiarity and obtain repetitive drop across them. The environmental extremes of the various tests were well within the limits of the relays, environmental sealing, and operational capabilities. Consequently, it was presumed that only a minimum percent of MVD change was due to the relay as a circuit element. The main contributors to the overall change were the FCC test leads and the low-profile connecting device.

TABLE 14.—FIRST-GENERATION TEST DATA

Sample	Initial DWV	Initial IR	Failure location (conductor no.)	Cause of failure
A1	OK	OK	—	MVD instrumentation unsuccessful (jumpers open circuited)
A2, 3, 4	—	—	—	—
A5	Fail	Fail	13-14, 16-17, 17-18	Partial disbonding of webs between three pairs of conductors
A6	OK	OK	—	—
A7	Fail	OK	1-2, 8	Disbond (1-2), crack outer jacket (8)
A8	Fail	OK	2, 10-11	Sharp corner (2), weak bond (10-11)
A9	OK	OK	—	—
A10	OK	OK	—	—
A21	OK	OK	—	—
A22	OK	OK	—	—
A23	OK	OK	—	—
A24	OK	OK	—	Bonds somewhat irregular
A25	OK	OK	—	Bonds somewhat irregular
A26	OK	OK	—	—
A27	OK	OK	—	—
A28	Fail	Fail	2, 3, 4, 8, 18-19	Pinholes except disbond (18-19)
A29	OK	OK	—	—
A30	OK	OK	—	—

TABLE 15.—MTSM CONCEPT PERMANENT SPLICE TERMINATION MVD CHANGE WITH ENVIRONMENT

TABLE 15.—MTSM CONCEPT PERMANENT SPLICE TERMINATION IN VOLTAGE														
Sample code and conductor number	Electrical continuity		Splice voltage drop, mV										Equal lengths of FCC	
	Through- spliced conductor	Jumpered conductors for MVD	Initial test	After thermal shock	After thermal aging	After vibration ^a	After moisture	After salt fog	Current cycling, b hr					
									50	100	150			
A2-2	OK	OK	4.87	4.75	4.82		4.89	4.89					6.04	
A2-3	OK	OK	4.78	4.66	4.69		4.67	4.65					6.04	
A2-12	OK	OK	4.84	4.77	4.79		4.78	4.75					6.04	
A2-13	OK	OK	4.86	4.76	4.80		4.78	4.77					6.04	
A3-2	OK	OK	5.33	5.18	5.19		5.16	5.11					6.04	
A3-3	OK	OK	5.11	5.02	5.04		5.04	4.99					6.04	
A3-12	OK	OK	5.09	5.02	5.02		5.05	5.00					6.04	
A3-13	OK	OK	4.98	4.91	4.93		4.92	4.88					6.04	
A4-2	OK	OK	4.86	4.74	4.79		4.77	4.74					6.04	
A4-3	OK	OK	4.91	4.86	4.83		4.79	4.80					6.04	
A4-12	OK	OK	4.71	4.62	4.62		4.60	4.60					6.04	
A4-13	OK	OK	4.64	4.58	4.59		4.61	4.56					6.04	

^aNot required; accepted by similarity.^bTest waived by agreement with technical monitor.

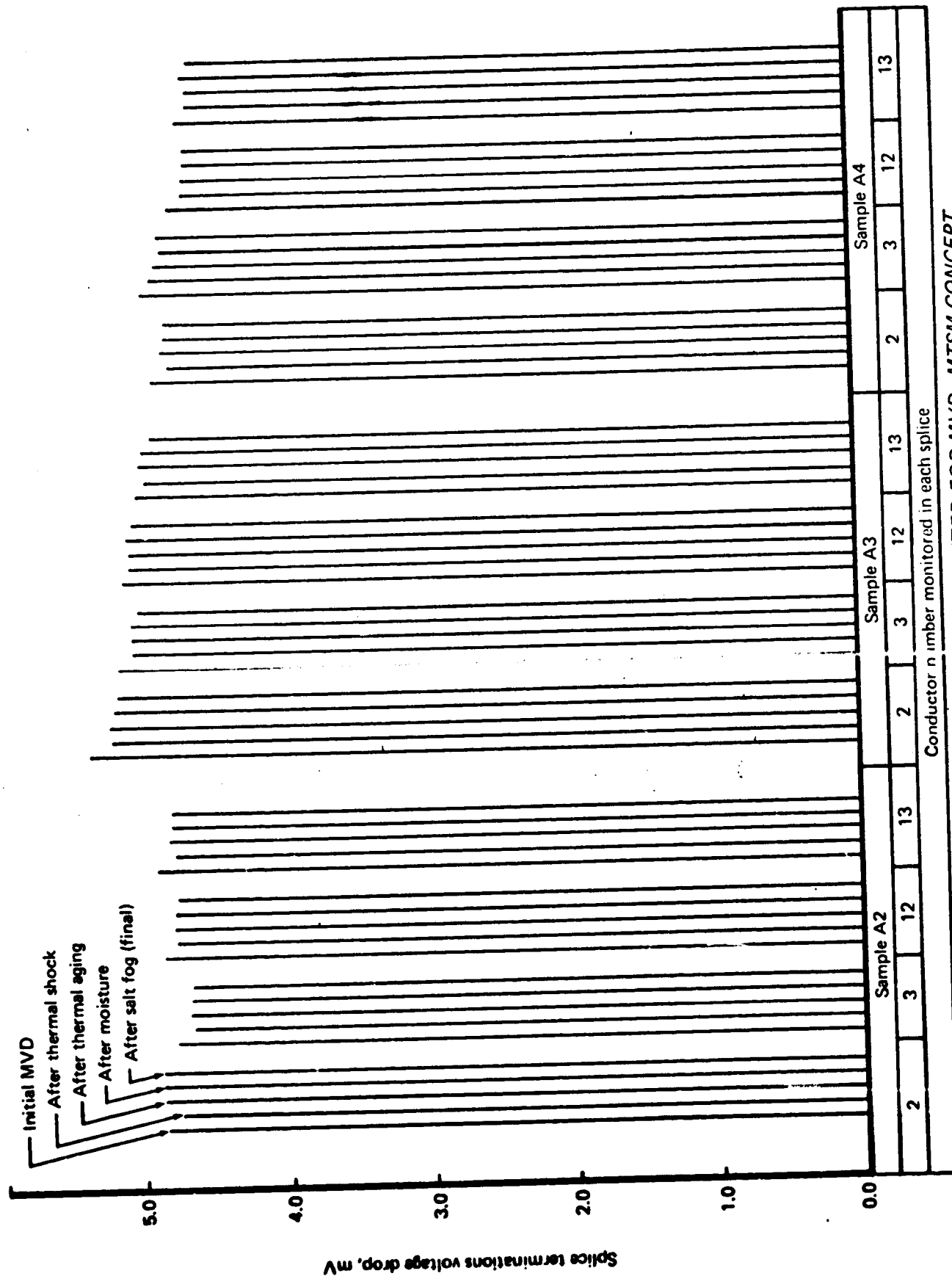


FIGURE 31.—FCC-TO-FCC SPLICES INSTRUMENTED FOR MVD—MTSM CONCEPT

TABLE 16.—MTSM CONCEPT PERMANENT SPLICE INSULATION RESISTANCE
AND DIELECTRIC WITHSTAND VOLTAGE TEST DATA SUMMARY

Sample code	Insulation resistance and dielectric withstand voltage					Failure details			
	Initial test	After thermal shock	After thermal aging	After moisture	After salt fog (final)	Fail-d condu- tors	Location (conductor no.)	Type	Voltage, min
A1	OK	N/R	N/R	N/R	OK	Noie	—	—	—
A2	OK	OK	OK	Fail	Fail	5	5, 6, 7, 8, 9	Breakdown to adjacent and solution	1500
A3	OK	OK	OK	Fail	Fail	2	6, 7	Breakdown to adjacent	10
A4	OK	OK	OK	OK	OK	Noie	—	—	—
A5	OK	OK	OK	Fail	Fail	7	1, 2, 3, 15, 16, 17, 18	Breakdown to adjacent and solution	700
A6	OK	N/R	N/R	OK	OK	Noie	—	—	—
A7	OK	OK	OK	N/R	OK	Noie	—	—	—
A8	OK	N/R	N/R	Fail	Fail	1	1	Breakdown to solution	12
A9	OK	N/R	N/R	N/R	OK	Noie	—	—	—
A10	OK	N/R	N/R	N/R	OK	Noie	—	—	—
A21	OK	N/R	N/R	N/R	OK	Noie	—	—	—
A22	OK	OK	OK	Fail	Fail	3	17, 18, 19	Breakdown to solution and adjacent	1500
A23	OK	OK	OK	OK	OK	Noie	—	—	—
A24	OK	OK	OK	OK	Fail	4	16, 17, 18, 19	Breakdown to solution	1500
A25	OK	OK	OK	Fail	Fail	4	14, 15, 16, 17	Breakdown to solution	10
A26	OK	N/R	N/R	OK	OK	Noie	—	—	—
A27	OK	OK	OK	N/R	OK	Noie	—	—	—
A28	OK	N/R	N/R	OK	OK	Noie	—	—	—
A29	OK	N/R	N/R	N/R	OK	Noie	—	—	—
A30	OK	N/R	N/R	N/R	OK	Noie	—	—	—

^aMVD instrumented

N/R = test not required per sequence.

The effect of the environmental sequence on test samples shows as an increase in the MVD values ranging from 4.3% to 40% at the end of testing. In addition, the properties of the insulating materials have been adversely affected, mostly after exposure to moisture, as evident from the failure of insulation resistance to meet the 100 M Ω requirement.

Dielectric withstand voltage test results in all cases indicated leakage currents greater than the 2 mA standard. Physical examination of the FCC cables showed severe discoloration of the unplated copper conductors. This did not appear to follow a particular pattern or to be limited to a specific area but was spread randomly over the entire length and on both sides of the cables.

The supplier of the FCC inspected the discolored cables and stated that this form of discoloration is a new experience. Discoloration due to pinholes in the Kapton have a distinct pattern spreading out from the pinhole. It was categorically stated that the discoloration was not due to pinholes.

Both the supplier of the cable and DuPont requested samples of the cable for chemical analysis.

These findings have caused doubt as to the most susceptible point for moisture to enter and cause failure. Three components were likely candidates: the flat cable, the relay-to-device interfacial seal gasket, and the silicone/glass-filled case and cover.

In an attempt to isolate the component that could be independently responsible for the initiation and subsequent failures, test sample D5 was elected for posttest analysis because it failed to meet both the dielectric (DWV) and insulation resistance (IR) requirements. The following is a step-by-step description of the analysis procedure and findings:

Step 1.—Results of the IR and DWV measurements, as taken immediately after completion of the salt fog test, were recorded in column 1 of table 17.

Step 2.—IR and DWV measurements were repeated after 72 hr of conditioning at ambient room temperature (72°F) and relative humidity (38%). Results were recorded in column 2 of table 17. A comparison of columns 1 and 2 reveals a considerable change in the IR values.

Step 3.—The flat cable test lead ends were then cut 2 in. to eliminate any possibility of foreign debris or salt crystals forming a path between conductors. Freshly cut ends were then stripped and prepared for testing. IR and DWV measurements were repeated and results recorded in column 3 of table 17. This step resulted in further change with IR and DWV both improving, as evident by comparing columns 2 and 3.

TABLE 17.-LOW-PROFILE DEVICE ENVIRONMENTAL TEST DATA

Sample code and pin no.	1 After salt fog		2 After 3 days at room temperature		3 After test lead ends cut and contamination removed		4 After pressure clip removed		5 Unmated device as is; no cleaning attempted		6 Unmated device assembly cleaned in solvent (MEK)	
	IR, ohm	DWV	IR, ohm	DWV	IR, ohm	DWV	IR, ohm	DWV	IR, ohm	DWV	IR, ohm	DWV
D5-A1	3 M	Leak 500	330 M	Leak 500	650 M	OK	650 M	OK	OK	OK	OK	OK
D5-A2												
D5-A3	3 M	Leak 20	700 M	Leak 20	OK	OK	OK	OK	OK	OK	OK	OK
D5-B1	2 M	Leak 10	60 M	Leak 20	120 M	OK	120 M	OK	OK	OK	OK	OK
D5-B2												
D5-B3	14 k	Leak, breakdown 20	8 k	Leak 20	5.5 k	Leak 20	5.5 k	Leak 20	10 k	Leak 20	10 k	Leak 20
D5-C1	200 k	Leak 100	19 M	Leak 50	20 M	OK	20 M	OK	120 M	OK	120 M	OK
D5-C2												
D5-C3	8 k	Leak 50	7.5 k	Leak 50	10 k	Leak 50	10 k	Leak 30	14 k	Leak 50	3 k	Leak 50
D5-D1	1.4 M	Leak 200	2.2 M	Leak 20	25 M	OK	25 M	OK	OK	OK	OK	OK
D5-D2												
D5-D3	6 M	Leak 100	540 M	Leak 200	900 M	OK	900 M	OK	OK	OK	OK	OK

TABLE 17.—Concluded

Sample code and pin no.	7 Cut FCC(B) (leave 2 in. with device) test FCC(B)			8 2 in. FCC(B) with device tested			9 Unglued case cover; ^a examined inside; observations	10 Relay as is, uncleaned, after unmate			Observations
	IR, ohm	DWV		IR, ohm	DWV			IR, ohm	DWV		
D5-A1							FCC(A) was examined and found perfect—weld and ends of conductors	OK	OK		All pins were examined and found very clean. No deposits of dirt or corrosion products were present. Relay surface was very clean at the meeting interface.
D5-A2								OK	OK		
D5-A3								OK	OK		
D5-B1	OK	OK		720 M	OK		Noticeable carbon breakdown on edge of Kapton; encapsulant A to B is well formed and well bonded; no voids or bubbles in area of breakdown	OK	OK		
D5-B2											
D5-B3	OK	OK		10 k	Leak at 20			OK	OK		
D5-C1								OK	OK		
D5-C2											
D5-C3								OK	OK		
D5-D1								OK	OK		
D5-D2											
D5-D3								OK	OK		

^aCase cover showed separation of peripheral bond,
1/3 of total, but complete bond to Sylgard 184.

Step 4.—The low-profile device clamp was removed but the device remained mated to the relay hardware (washers and nuts of the clamp assembly were severely corroded). IR and DWV values were recorded in column 4. No change was observed.

Step 5.—The device was carefully unmated from its relay and tested immediately. No cleaning was attempted and handling was minimized. Results were recorded in column 5 of table 17. When comparing values of columns 4 and 5, a change in the IR was noted bringing the device closer to meeting the requirements. It was concluded that the gasket between the relay and the low-profile connecting device contributed to the initial failure indications reported in step 1 but was not the only source of failure.

Step 6.—The mating surface of the device was thoroughly cleaned with MEK solvent to ensure that no dirt or surface moisture connected the exposed socket edges. Data were recorded in column 6 of table 17. No change was noted.

Step 7.—Having narrowed the failure location to cables B and C and their contacts, it was decided to cut cable B leaving 2 in. of it connected to the device. Cable B was chosen because it was the most severely discolored. The cut segment of cable B was then tested for IR and DWV with no failure noted despite its discoloration. With the cable eliminated, the failure had to be inside the device itself.

Step 8. The remainder of cable B with the device was then tested and found faulty (column 8 of table 17).

Step 9.—At this time, it was necessary to open the case and examine each layer of cable with its contacts. The case cover bond was observed to have separated from the case edge about one third of the periphery but was completely bonded to the Sylgard potting. The transparent nature of the sylgard permitted close examination, with the aid of a magnifier, of cable A without disturbance. The cable with stripped ends and soldered joints was found in perfect condition. Cable A was then lifted to gain access to cable B. The bond between cables A and B was well formed and with no voids or bubbles. The possibility of moisture penetration between the two cables seemed unlikely (see fig. 32).

Examination of cable B led to the location of the dielectric breakdown with noticeable carbon deposits bridging the gap between conductors B2 and B3. The breakdown arc occurred at the recessed end of the stripped Kapton edge. The macrophotograph of figure 33 shows the details and location of the failure. The condition of cable C was similar to B.

REPRODUCIBILITY OF THE ORIGINAL PART IS POOR,

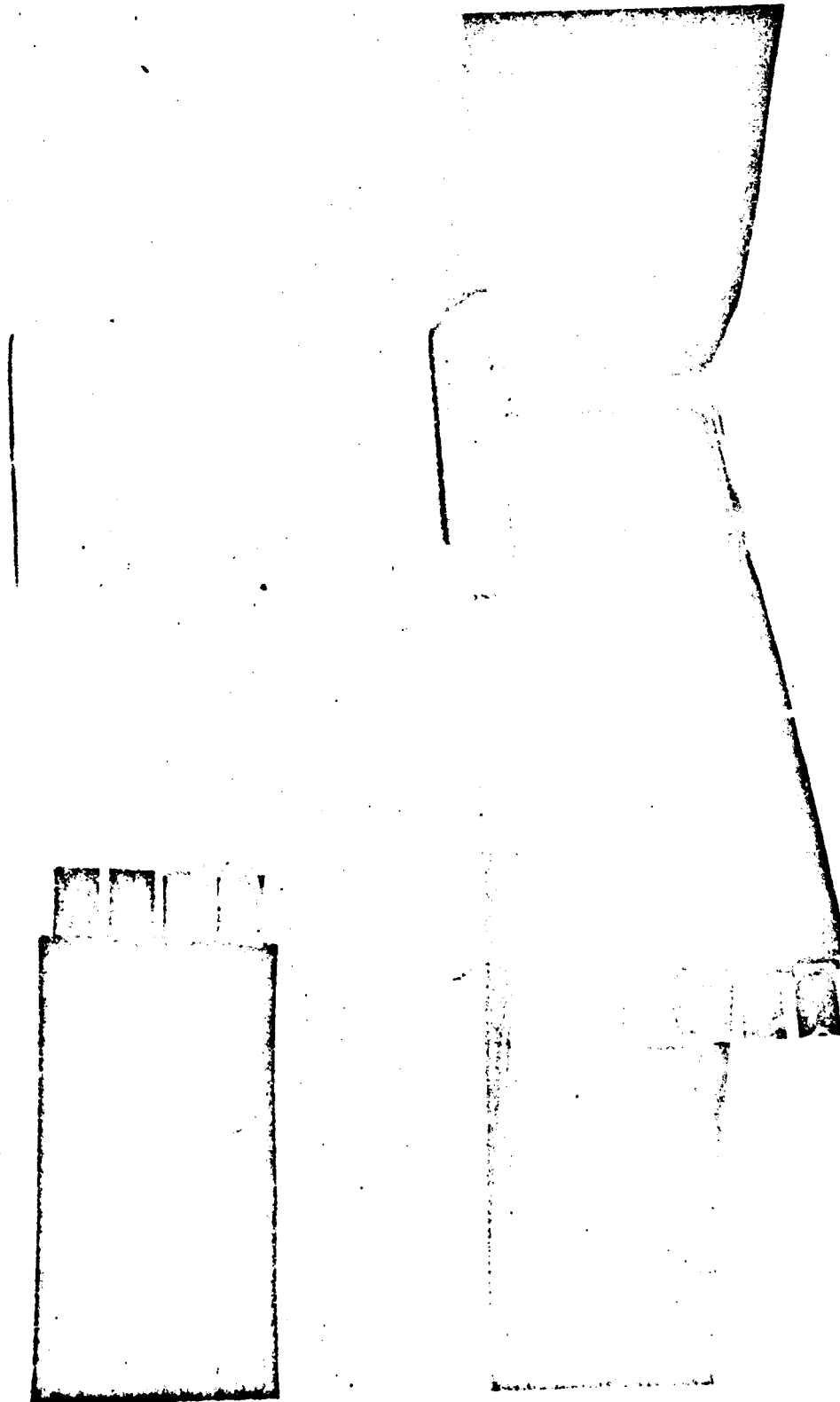


FIGURE 32.—LOW-PROFILE CONNECTING DEVICE AFTER TEST

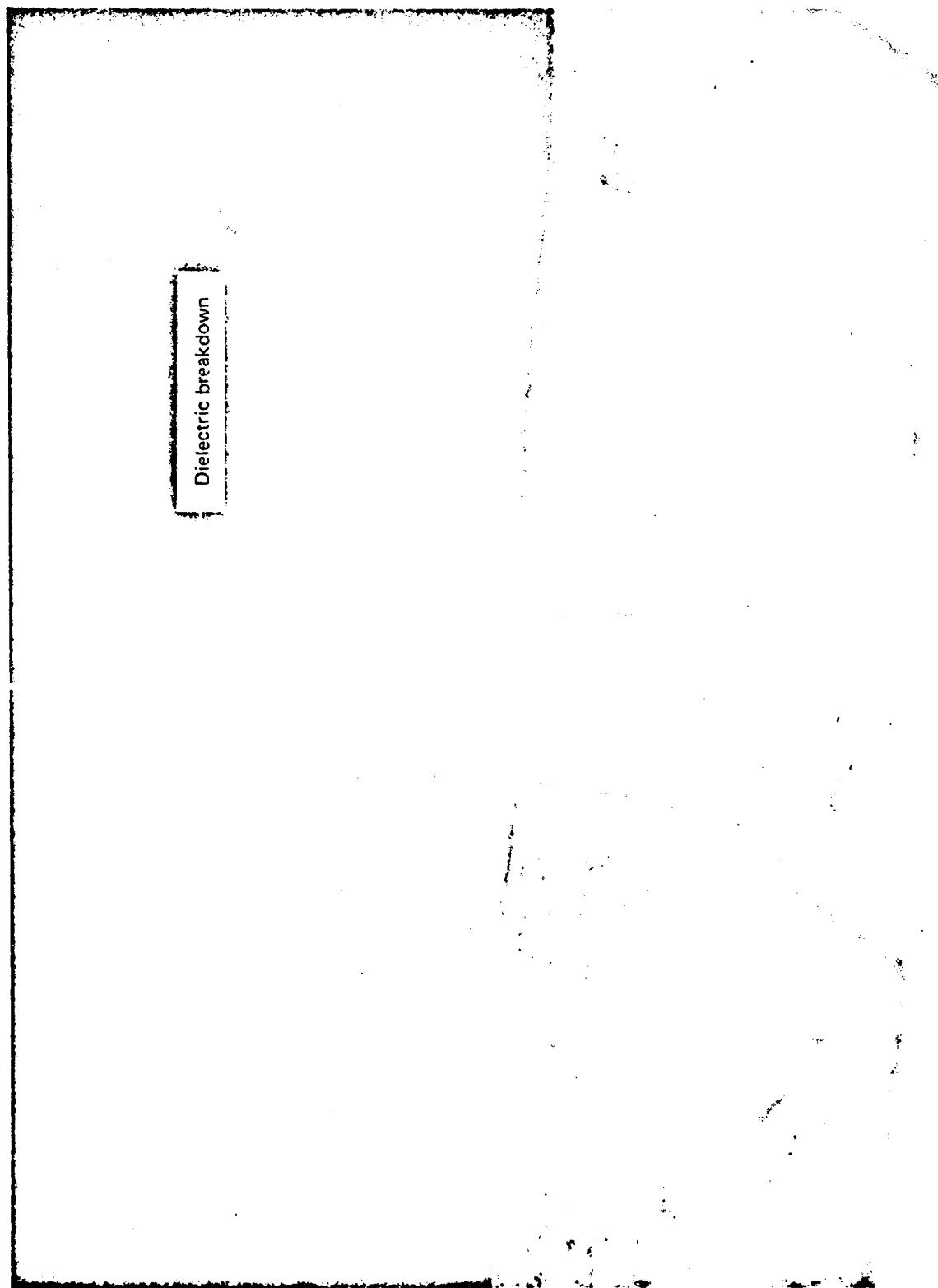


FIGURE 33.--MACROPHOTOGRAPH OF DIELECTRIC BREAKDOWN

Step 10. --The relay was tested without the device and was found to meet the IR and DWV requirements. All pins were found very clean with no deposits, dirt, or corrosion products. The relay gasket displayed impressions of the socket seatings indicating the effectiveness of the clip clamping arrangement.

Permanent Splice Data Analysis

A-MP Crimp "Box" Concept 1 Analysis

Examination of values listed in table 12 shows that the crimp joint results in MVD values that vary over a wide range (12.90 mV to 22.82 mV initial), and the spread is maintained throughout the test sequence. This trend indicates that crimping through insulation does not produce electrically similar and repetitive joints. In addition, when compared to unspliced lengths of conductor, the crimped-through splice has double the resistance at best. This could have been a result of the increased length of crimp contact and the additional welded joint that was necessary to join the two crimp contacts that make up the splice. On the other hand, it was observed that, once a crimp joint is made, it remains stable throughout the environmental conditioning (5.35% change maximum). This stability indicates an effective and reliable electrical performance. From figure 30, it is noted that conductor 2 of sample B3 has developed an unusually high drop. This seems to be the exception rather than the rule and for all practical purposes could be neglected.

The effectiveness of the insulating material and the "box" casing arrangement can be assessed by evaluating the results in table 13. It was observed that the dominant type of failure was in the form of leakages to adjacent conductors with the majority occurring at the conductors instrumented for MVD. Soldering short jumpers on the conductors proved to be a difficult task with the disadvantage of damaging the conductor and insulation and in some cases establishing, via solder fingers, electrical shorts between conductors (sample B24).

The number of conductors failed at the end of the test sequence was 57 out of a total of 380 or a failure rate of 15%. Note that this failure rate includes all the test samples of which some did not go through the complete test sequence.

MSTM Concept 3 Analysis

Failures experienced with first-generation samples resulted in the following observations:

- The monitoring jumper technique used proved to be inadequate. The solder in the pre-soldered splices without the flat conductor (used as monitoring lead) would cause the solder to flow out at random during the heat cycle process. This could cause a short between conductors or reduce the dielectric to cause a failure under voltage stress.

All three samples with the monitoring leads (A2, A3, A4) had similar faults (flow of solder) so that conductors 1 and 2 (and possibly 3) and 12 and 13 (plus 11 and 14) were disqualified for the transition splice tests. To correct this type of failure, a high-temperature solder was used on second-generation samples.

- o Other failures with these early test samples were caused by partial unbonding of the dielectric (Kynar) web between adjacent splices, pinholes in the MTSM jacket caused by misalignment of the heating tool, and sharp corners in the presolder splice insert. Design improvements were performed by Raychem and are discussed under "Fabrication."

The second generation of samples with the improved design displayed consistent and stable splice millivolt drop (fig. 29) initially and at the completion of tests. All splice junctions were more efficient electrically (5.11 mV maximum) than unspliced FCC conductors (6.04 mV).

Insulation and dielectric failures on second-generation samples were experienced at 26 conductors out of a total of 380 conductors tested. All failures occurred after moisture and salt tests. Breakdown of dielectric was visually observed as a spark either between adjacent conductors or between a single conductor and ground (salt solution). The location of failure was circled on the sample for easy identification. In almost all cases, breakdown occurred at the ends of the splice-solder-coated copper inserts in both FCC to FCC and FCC to RCC. Figure 34 shows some typical locations.

Close examination with the aid of a magnifier of the damaged areas in one sample revealed an air bubble bridging over most of the gap between two adjacent conductors.

Other observations revealed delamination between the splice outer jacket and the sealing material, mostly in FCC-to-RCC splices. The extent of delamination varied from initial stages on some samples to severe delamination with over half of the area delaminated on others. Figure 35 is representative.

Raychem was informed of these results, and corrective improvements were incorporated in the form of jacket redesign, improved bonding, increased sealing capability, and controlled flux. No hardware with these improvements was made or tested.

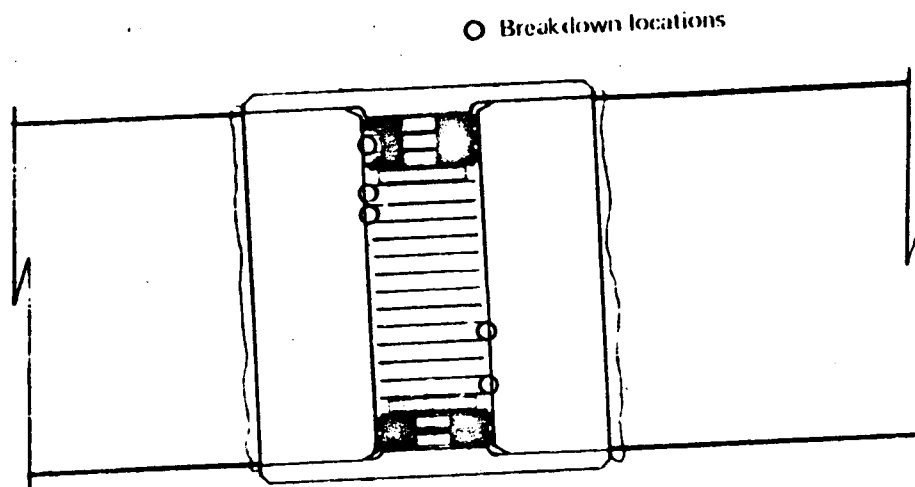


FIGURE 34.—TYPICAL DIELECTRIC BREAKDOWN LOCATIONS

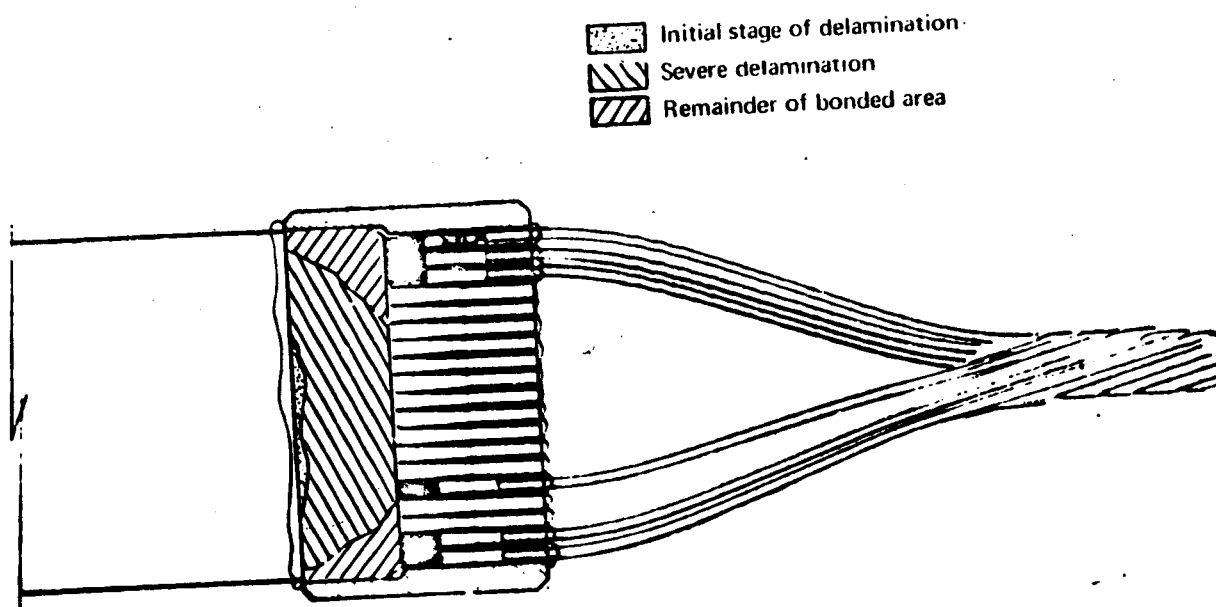


FIGURE 35.—SPlice DELAMINATION

CONCLUSIONS

LOW-PROFILE CONNECTING DEVICE

The results of the program indicate that the design and fabrication and processing techniques are feasible and practical. With some redesign, the low-profile goal (maximum height of 3/8 in.) can be met.

After humidity exposure, a portion of the test samples failed to meet the test requirements for IR and DWV. Salt spray exposure caused additional failures. However, after a period at room conditions, the samples recovered (dried out) sufficiently to meet IR and DWV. Examinations of samples that failed in dielectric breakdown tests, showed that the insulation edge on the FCC where it had been stripped was the point of breakdown.

A posttest failure analysis was performed on test sample D5. The resulting data are included in table 17. The conclusions that can be reached from the data presented are as follows:

- Subsequent to salt fog (step 1), all circuits tested resulted in failure readings; subsequent to 3 days at room temperature conditions (step 2), three circuits had satisfactory IR readings but experienced little or no improvement in DWV results.
- Subsequent to removal of the ends of the FCC leads (step 3), satisfactory readings were obtained on DWV for six of the eight circuits tested.
- Subsequent to steps 4, 5, and 6, the six circuits indicating satisfactory DWV from step 3 had also tested OK for IR values.
- The two failed circuits remaining were found to have a breakdown between them at the device termination end located at the strip line of the FCC lead.

As a result of this analysis, it has been shown that two failures occurred within the device (table 17), and the other failures were caused by lack of integrity of the ends of the test leads of the FCC. Specifically, the relay in this case was not responsible for the failures experienced (step 10). For future studies of this type device, particular attention should be directed to:

- Processing of the terminations of the FCC to ensure that contaminants are not present from such operations as stripping or soldering

- Ensuring that encapsulation material and processing are not subject to either moisture absorption or lack proper adhesion properties in the application used
- Providing a device-to-component interfacial sealing gasket "design" and "installation" for the required environments
- Protecting the ends of the test leads from the test environments to ensure that test results are pertinent to the test sample and not due to test lead contamination.

PERMANENT SPLICE "BOX" CONCEPT

The results of the permanent splice investigations led to the following conclusions:

- The crimp-through insulation technique does not produce a joint better than or equal to the cable. However, a higher resistance should be considered acceptable, provided it is repeatable and remains stable in operation. Two of the samples had higher readings, but the remaining ones do show repeatability and all joints showed consistency in environmental cycling. Further studies with larger sampling are required to establish the trend. Also, improved crimp techniques to establish lower resistance values should be studied.
- The "box" encapsulation concept showed simplicity of processing. However, case material was more brittle than desired for this application and the encapsulant used (Sylgard 186) requires an excessive cure time for a production application.

Both this concept (concept 1) and concept 3 permanent splices showed good joint electrical stability with minimal change of MVD initial and final values. However, it was concept 3 that compared more favorably with unspliced lengths of FCC conductor. The solder splices were of low resistance and repetitive in performance. With respect to sealing and dielectric separation, concept 3 had a lower failure rate. One major fault of concept 3 was the delamination of the outer jacket of the splice.

Table 18 compares the MVD percent change of concept 1 with that of concept 3 for splice electrical stability before and after environmental exposure.

TABLE 18.—SPLICE TERMINATIONS—MVD STABILITY

MTSM concept							A-MP crimp concept				
Sample code and conductor number	Termination MVD at 3A			Length between voltage-sensing leads, in.	M/D of equal lengths of :CC	Sample code and conductor number	Termination MVD at 3A			Length between voltage-sensing leads, in.	MVD of equal lengths of FCC
	Initial	Final	O/O change				Initial	Final	O/O change		
A2-2	4.87	4.89	+0.41	13/16	6.04	B2-2	21.16	19.55	-7.61	13/16	6.04
A2-3	4.78	4.65	-2.71	13/16	6.04	B2-3	13.27	13.48	+1.58	13/16	6.04
A2-12	4.84	4.75	-1.85	13/16	6.04	B2-12	14.02	14.77	+5.35	13/16	6.04
A2-13	4.86	4.77	-1.85	13/16	6.04	B2-13	14.16	14.43	+1.91	13/16	6.04
A3-2	5.33	5.11	-4.13	13/16	6.04	B3-2	22.83	28.61	+25.4	13/16	6.04
A3-3	5.11	4.99	-2.35	13/16	6.04	B3-3	15.76	16.00	+1.52	13/16	6.04
A3-12	5.09	5.00	-1.77	13/16	6.04	B3-12	14.34	14.28	-0.42	13/16	6.04
A3-13	4.98	4.88	-2.01	13/16	6.04	B3-13	14.47	15.04	+3.94	13/16	6.04
A4-2	4.86	4.74	-2.47	13/16	6.04	B4-2	12.90	13.22	+2.48	13/16	6.04
A4-3	4.91	4.80	-2.24	13/16	6.04	B4-3	13.13	14.44	+2.36	13/16	6.04
A4-12	4.71	4.60	-2.34	13/16	6.04	B4-12	14.11	14.15	+2.83	13/16	6.04
A4-13	4.64	4.56	-1.72	13/16	6.04	B4-13	13.10	13.24	+1.07	13/16	6.04

RECOMMENDATIONS FOR FOLLOW-ON

In each of the development items, it is clear that additional work is required to optimize designs and processes. Accordingly, the following recommendations are proposed:

LOW-PROFILE CONNECTING DEVICE

The failures experienced after humidity and salt fog exposure clearly indicate the need for redesign in the areas of selection of material and special precautions to be taken during processing. The key items in the recommended program would be:

- Continue testing the device through current cycling tests at temperature. This may provide a more definitive fault mode.
- Conduct detailed material analyses with respect to ease of fabrication, cost effectiveness, and stability over its anticipated service life.
- Test and select materials that will reduce processing time and "cure" time.
- Optimize the design in the area of socket contact, configuration, contact retention, termination (FCC to socket), and interfacial seal.
- Prepare design configurations for a total "family" of typical aerospace components.

PERMANENT SPLICES

Both concepts show feasibility of fulfilling the requirements of a permanent splice with some redesign and development testing.

Concept 1-Box

The advantages of automatic crimping at a high rate is a strong motivation to pursue the crimp approach. The higher splice resistance is acceptable, provided it is stable and repeatable. Accordingly, additional testing with manufacturer coordination is recommended. Further, splices with higher current ratings (above 3 amp) should be pursued.

The box encapsulation technique can be optimized, and the following are recommended for follow-on activities:

- Conduct material analyses to select case material that would be less brittle and remain bondable.
- Conduct a survey and tests to select a good sealant with a short "cure" time. A one-part sealant, as opposed to the two-part sealant used in this development program, would be desirable.
- Optimize case design to provide a snap-in self-locking feature to hold the two halves together.

Concept 3—MTSM

This concept showed an encouraging degree of success, and the failure analysis has already produced a third-generation improved design. Additional development and testing are therefore recommended to optimize the design. Further, materials to meet the 200°C environment should be used to provide an MTSM that would qualify for operation at higher temperature environments.

Ultrasonic Welding

The concept of ultrasonic welding of the conductors and ultrasonic welding of case or housing to encapsulate the joint has exciting possibilities. A 12- to 18-month feasibility program would cover:

- Ultrasonic welding studies of typical flat conductor cables (AWG 22 to 30), which would be tensile tested and compared with the designs tested in this program
- Ultrasonic welding of case material after an industry survey of materials already being welded
- Ultrasonic welding of case-material-to-conductor insulations, using Tefzel and similar materials, to make the case a homogeneous extension of the cable insulation after processing the conductor.

Flat Conductor Cable

The unplated copper FCC (AWG 25) discoloration problem should receive the following further attention:

- Conduct chemical analyses to determine the chemical action that has taken place.
- Subject cables to environmental exposure to identify the exact conditions that caused the discoloration.
- Identify the cause and results of the "action" (can the cable function on a 100% basis?)

The trend to use unplated conductors for FCC is increasing, so the above study becomes urgent.

APPENDIX A

PROCESS SPECIFICATION FOR LOW-PROFILE CONNECTING DEVICE

A.1 SCOPE

This specification defines the fabrication and assembly procedures for a low-profile electrical connecting device for use with a Leach K-D4A-017 (BAC R1 3CG-2A) relay.

A.2 CLASSIFICATION

None

A.3 REFERENCES

- a) MIL-S-6872 Soldering Process, General Specification For

A.4 MATERIALS CONTROL

- a) Potting compound
Sylgard 184 Resin
Dow Corning Corp.
- b) Primer
Sylgard primer
Dow Corning Corp.
- c) Sealing compound
RT V-108
General Electric
- d) Flat conductor cable
2-mil FEP on 2-mil Kapton
Hughes Aircraft Company or Tape Cable Corp.

- e) Connector contact sockets
9-12062-1A-4
The Boeing Company
- f) Connector case
9-12062-1A-1
The Boeing Company
- g) Etchant
Tetra-Etch
W. L. Gore and Assoc., Inc.
- h) Methyl ethyl Keytone (MEK)
TT-M-261
- i) Naphtha, aliphatic
TT-N-95
- j) Relay, 4 PDT
K-D4A-017
Leach Corp.

A.5 MANUFACTURING CONTROL

A.5.1 Conductor Preparation

- a) Strip the flat conductor cable (A.4d) 5/16 in. using a Hughes blade stripper or equivalent.
- b) Round the square corners of the stripped conductors to conform with the surface of the contact (A.4e) see figure A-1
- c) Etch the flat conductor cable insulation $2 \pm 1/4$ in. in etchant A.4g or equivalent.
- d) Tin the conductors per MIL-S-6872

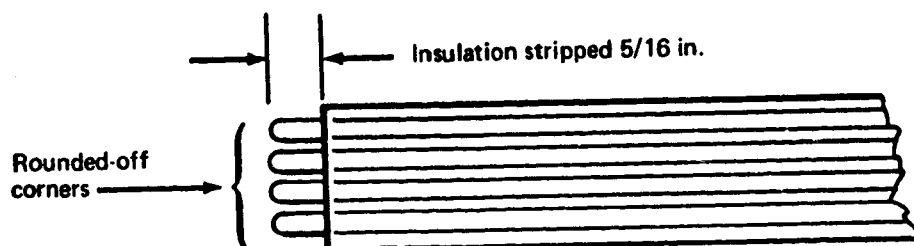


FIGURE A-1.—FLAT CONDUCTOR CABLE

A.5.2 Assembly of details

- a) Clean the contacts with MEK (4.4h) or naphtha (A.4i).
- b) Press fit the connector contact sockets (A.4e) into the connector case (A.4f) (see fig. A-2).
- c) Cover the face of the connector with a piece of pressure-sensitive tape to prevent contamination from entering the contact sockets.
- d) Place the connector case in a suitable holding fixture to restrain movement during the soldering operation.

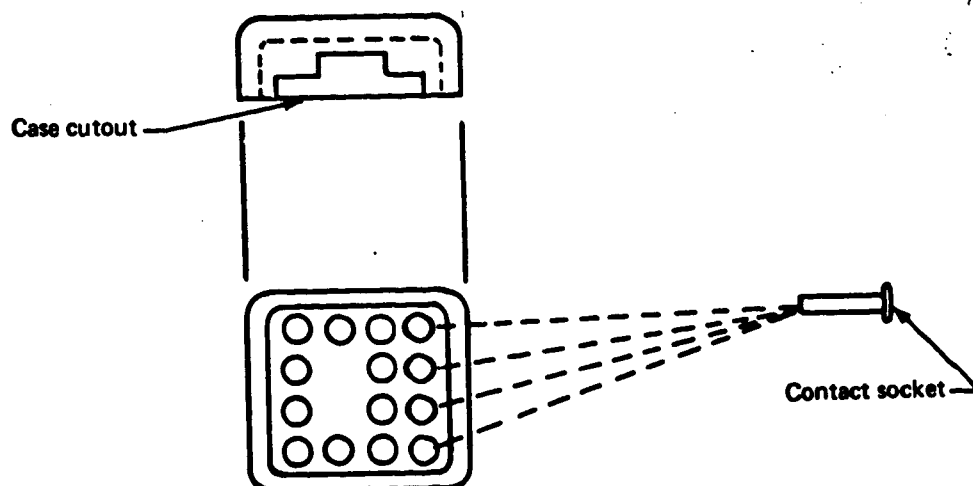


FIGURE A-2.—CONNECTOR CASE

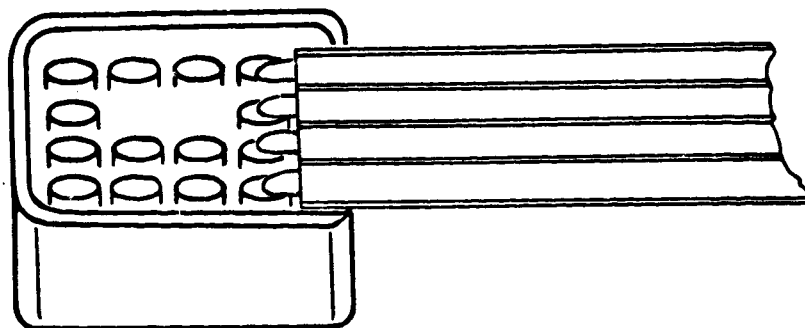
- e) Solder tin the contacts (A.4e) per MIL-S-6872. The contact surface should have a dome buildup of approximately 1/32 in. of solder.
- f) Assemble the first flat conductor cable as follows:
 - 1) Position the prepared cable (stripped and tinned conductors) over the first row of contacts (see fig. A-3).
 - 2) While depressing the conductors to the contacts, apply soldering iron and heat until the tinned surfaces become fluid.
 - 3) When the solder is fluid, remove the soldering iron, but do not disturb the connections until the solder has solidified.
 - 4) Repeat soldering operations 1, 2, and 3, above, for each layer of conductors (see figs. A-3 and A-4).
 - 5) Where there are no contacts in the case to connect conductors to, remove the stripped and tinned conductor by cutting it off at the insulation of the flat conductor cable.
 - 6) Clean the soldered assembly with MEK or naphtha (A.4h or A.4i) to remove flux residue.

A.5.3 Case and Cover Assembly

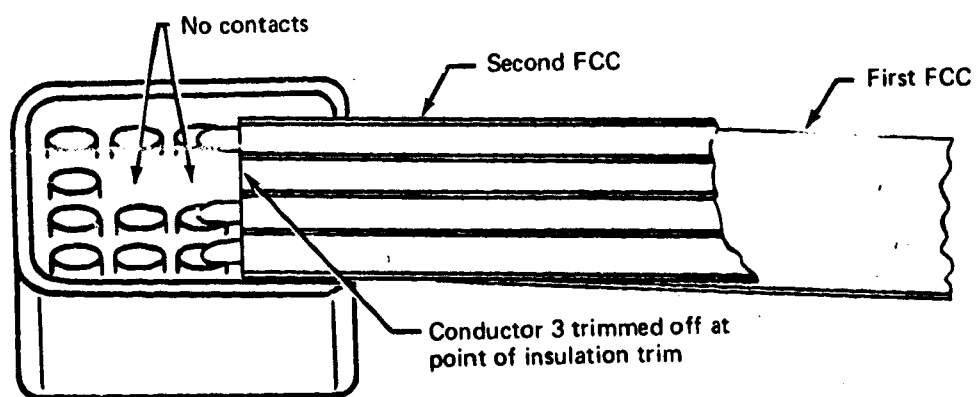
- a) Clean the case cover figure A-5 with MEK or naphtha (A.4h or A.4i).
- b) Apply a thin coating of RTV-108 sealing compound (A.4c) to the edge of the case and set the cover in place.
- c) Cure the assembly in an oven for 2 hr at 150°F.

A.5.4 Potting of Assembly

- a) Immerse the assembly in Sylgard primer (A.4b) and agitate for approximately 5 sec, then remove the assembly and drain off excess primer.
- b) Oven cure the primed assembly for 2 hr at 150°F.

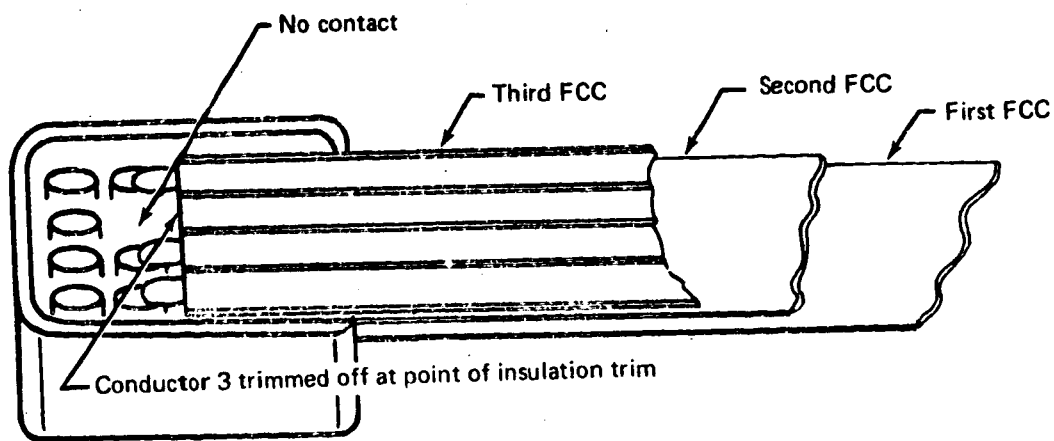


First Flat Conductor Cable Soldered in Place

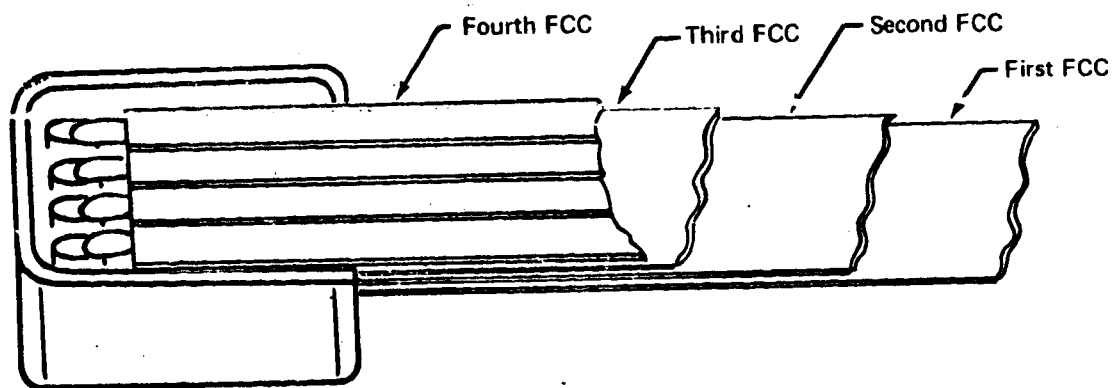


Second Flat Conductor Cable Soldered in Place

FIGURE A-3.—INSTALLATION OF FIRST AND SECOND FLAT CONDUCTOR CABLES
IN CONNECTOR CASE



Third Flat Conductor Cable Soldered in Place



Fourth Flat Conductor Cable Soldered in Place

FIGURE A-4.—INSTALLATION OF THIRD AND FOURTH FLAT CONDUCTOR CABLE IN CONNECTOR CASE

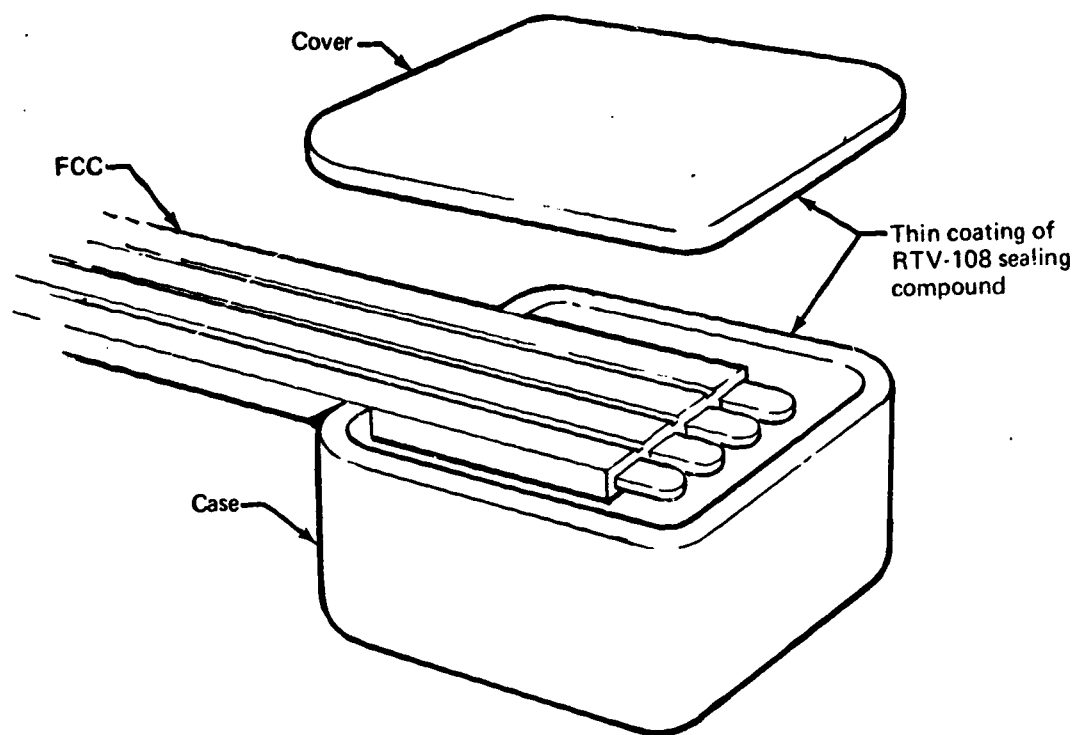


FIGURE A-5.—CASE AND COVER ASSEMBLY

- c) Mix Sylgard 184 potting compound (A.4a) per the manufacturer's instructions. De-aerate the compound in a vacuum until all bubbles have collapsed.
- d) Mount the case and flat conductor cable assembly in a fixture with the case cutout (opening) up, and the cables projecting vertically from the case.
- e) Pour the prepared potting compound into the case cutout (opening) slowly until about 1/3 full. Allow the material to settle, flow, fill voids, and release entrapped air.
- f) Complete the filling of the cavity and allow material to flow between the flat conductor cable layers.

NOTE: The finished potted assembly should have a fully potted case and a fillet of compound around the flat conductor cables.

- g) Room temperature cure the assembly for 24 hr, followed by an oven cure for 4 hr at 150°F.

A.5.5 Case-to-Relay Assembly

- a) Remove the protective tape from the case face (contact socket surface) and clean with MEK (A.4h) or naphtha (A.4i).
- b) Clean the contact pins with MEK (A.4h) or naphtha (A.4i).
- c) Position the silicone rubber gasket (furnished with the relay) over the relay contact pins and slide up to the base of the relay.
- d) Check positioning of relay contact pins and case sockets and insert relay into the case.

NOTE: Pin and socket connection must be made with a smooth steady pressure to avoid pin damage.

A.5.6 Typical Installation

- a) Figure A-6 shows typical installation on structure with a spring clamping device.
- b) Nuts used to secure a typical installation should be torqued to 8 in.-lb.

A.6 QUALITY CONTROL

The Quality Control Department shall ensure conformance with the requirements of this specification.

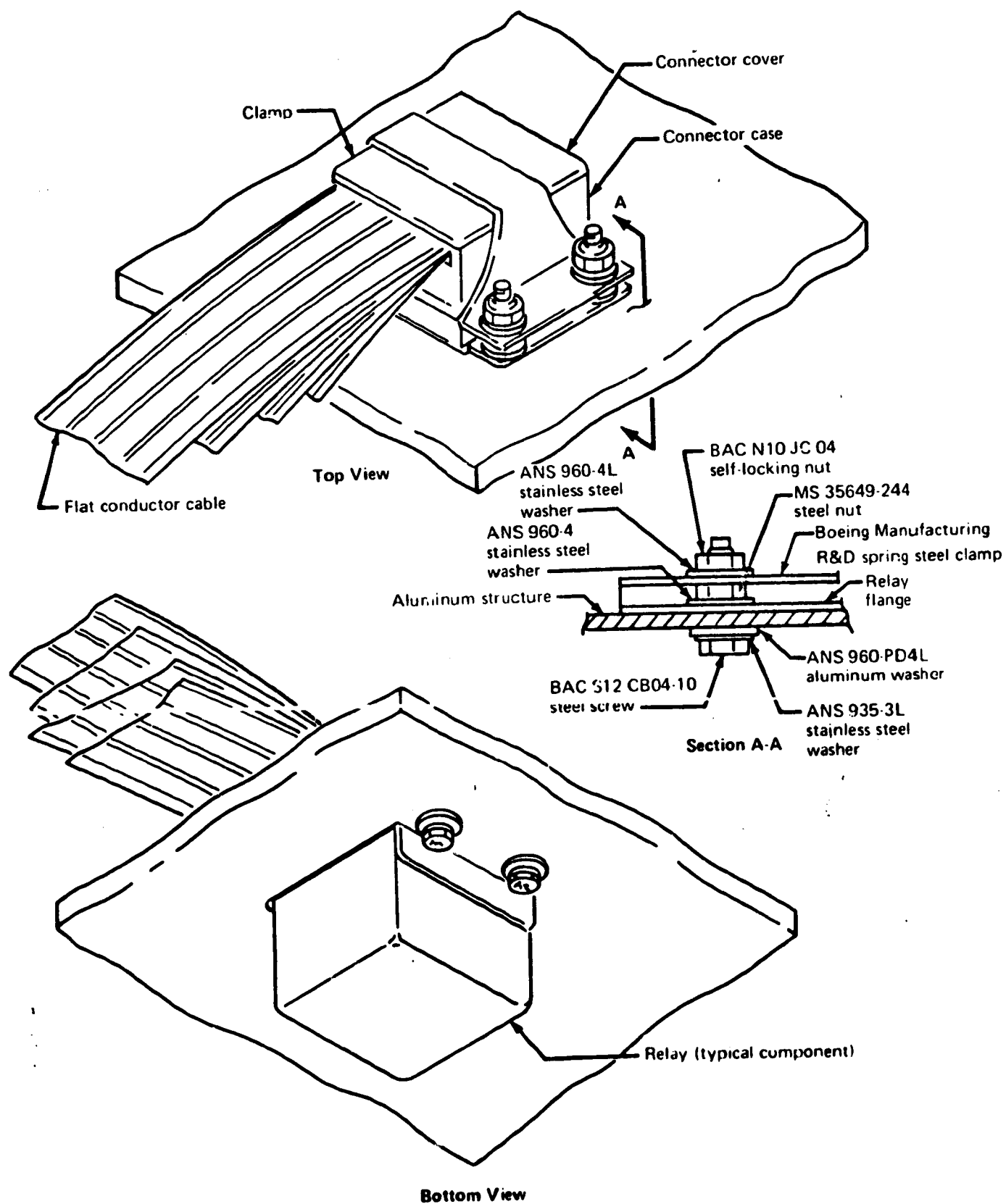


FIGURE A-6.—TYPICAL INSTALLATION

APPENDIX B

PROCESS SPECIFICATION FOR PERMANENT SPLICE

B.1 SCOPE

This specification establishes the requirements for terminating flat conductor cable (FCC) to flat conductor cable and flat conductor cable to round conductor cable (RCC) using a potted dielectric protective housing to cover the spliced area. All operations must be compatible with the installation of FCC-to-FCC and FCC-to-RCC splices in a fueled vehicle.

B.2 CLASSIFICATION

None

B.3 REFERENCES

- a) BAC 5153 Assembly of Electric Terminations
- b) BAC 5550 Potting of Electric Connectors
- c) BAC 5157 Process Specification for Fabrication of Electric Wire Bundles
- d) D2-6438 Requirements for Certification of Electrical Terminating Tools

B.4 MATERIALS CONTROL

Material "type" classifies materials according to maximum continuous operating temperature listed below. Where a drawing specifies a temperature "type" area, only materials of that classification may be used, except that when a specific material is not available, a higher temperature type may be substituted. When the specification or engineering drawing calls out a specific material, no substitutions shall be made. Generally, where temperature type or material are not specifically designated, type I material shall be used.

Type I	to 200°F
Type II	to 275°F
Type III	to 350°F
Type IV	to 500°F

- a) Box halves
9-12062-I-1, -2
The Boeing Company
- b) Potting compound
Sylgard 186 resin
Dow Corning Corporation
- c) Solvent
Methyl ethyl ketone (MEK)
TT-M-261
- d) Teflon etchant
Tetra-Etch
W. L. Gore and Assoc., Inc.
- e) Primer
Sylgard primer
Dow Corning Corp.
- f) Miscellaneous materials
Cheese cloth, lint free; any source*
Gause, lint free; any source*

B.5 FACILITIES CONTROL

- a) FCC cutoff tool
(Part number to be assigned later)
-

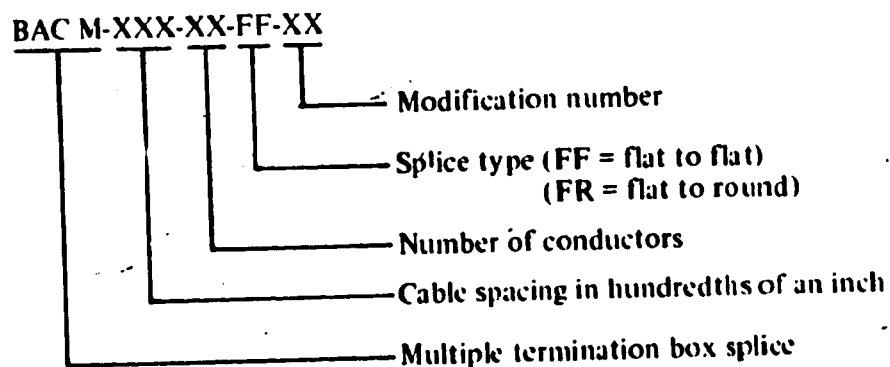
*Shall not contain more than 0.75% oil as determined by carbon tetrachloride extraction and calculated to a dry weight basis.

- b) Round wire stripper
ST 2222-26
Ideal Industries
- c) FCC hand crimp tool
90273-1
A-MP, Inc.
- d) Round wire hand crimp tool
90222-2 Certi Crimp
A-MP, Inc.
- e) Modified "Red Devil"
Model 510 pliers
Red Devil Co.

B.6 MANUFACTURING CONTROL

B.6.1 Part Numbering

- a) Part numbers of "box" termination splices are determined as follows:



- b) Typical splices are shown in figures B-1 and B-2.

B.6.2 Cable Preparation

Cut the end of the FCC square with the cutoff tool and strip the RCC per reference B.3c using tools per B.5. Then use the following procedure for assembling FCC-to-FCC or FCC-to-RCC "box" termination splices:

- a) Clean all splices with MEK solvent per B.4c.
- b) Etch the FCC in sodium solution such as Tetra Etch (B.4d) 3/4-in. from cut end of cable.
- c) Clean by water rinse followed by solvent clean with MEK (B.4c).
- d) Prime splice areas (3/4 in. from FCC end and 3/4 in. from RCC insulation end) and inside of box halves (B.4a) with Sylgard silicone primer and oven bake for 2 hr at $150^{\circ}\pm 5^{\circ}\text{F}$ to dry primer and remove moisture.
- e) Mix and degas Sylgard 186 potting compound (B.4b) per manufacturer's instructions.
- f) Crimp FCC-to-FCC or FCC-to-RCC terminal splices to cable with tooling B.5c or B.5d, depending on drawing requirements. Crimp per manufacturers' instructions. Typical assemblies are shown in figures B-1 and B-2.
- g) Fill box halves (B.4a) to overflowing to ensure void-free potting.
- h) Lay appropriate splice (table B-1) in one box half, centering the splice in the box as shown in figure B-3.
- i) Place the other box half in position to complete enclosure of splice and position the eyelets as shown in figures B-4 and B-5 prior to riveting.
- j) Squeeze box halves together forcing out excess compound and entrapped air.
- k) Set and crimp eyelets and remove excess potting compound.
- l) Room temperature cure for 24 hr, followed by oven cure at $150^{\circ}\pm 5^{\circ}\text{F}$ for 4 hr. Alternate process for curing potting compound installation on fueled vehicle consists of 3-day room temperature cure at $78^{\circ}\pm 5^{\circ}\text{F}$.

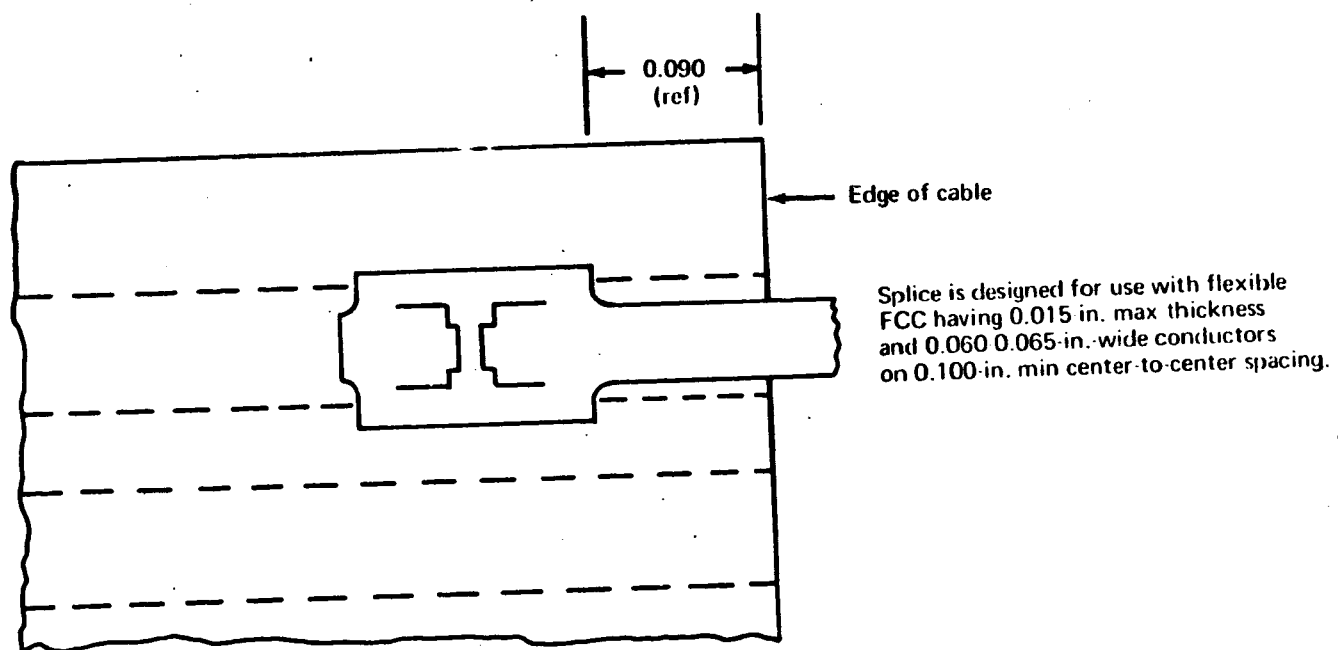


FIGURE B-1.—SPLICE FOR FCC TO FCC

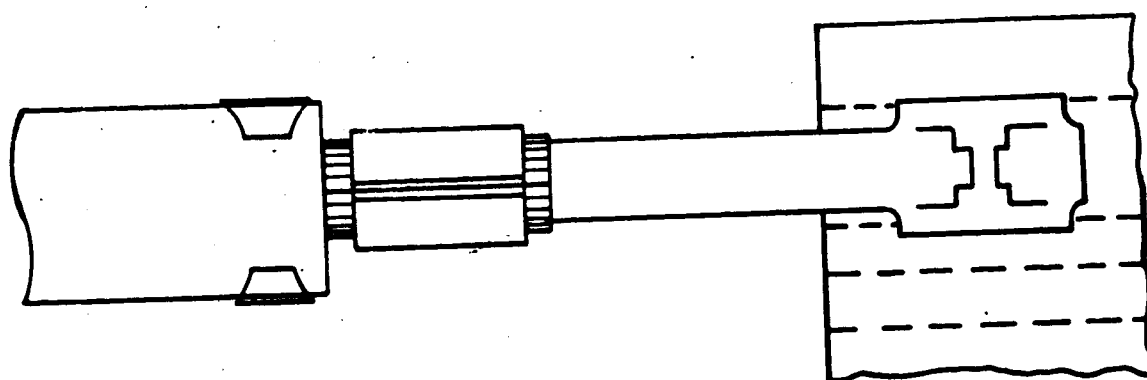


FIGURE B-2.—SPLICE FOR RCC TO FCC

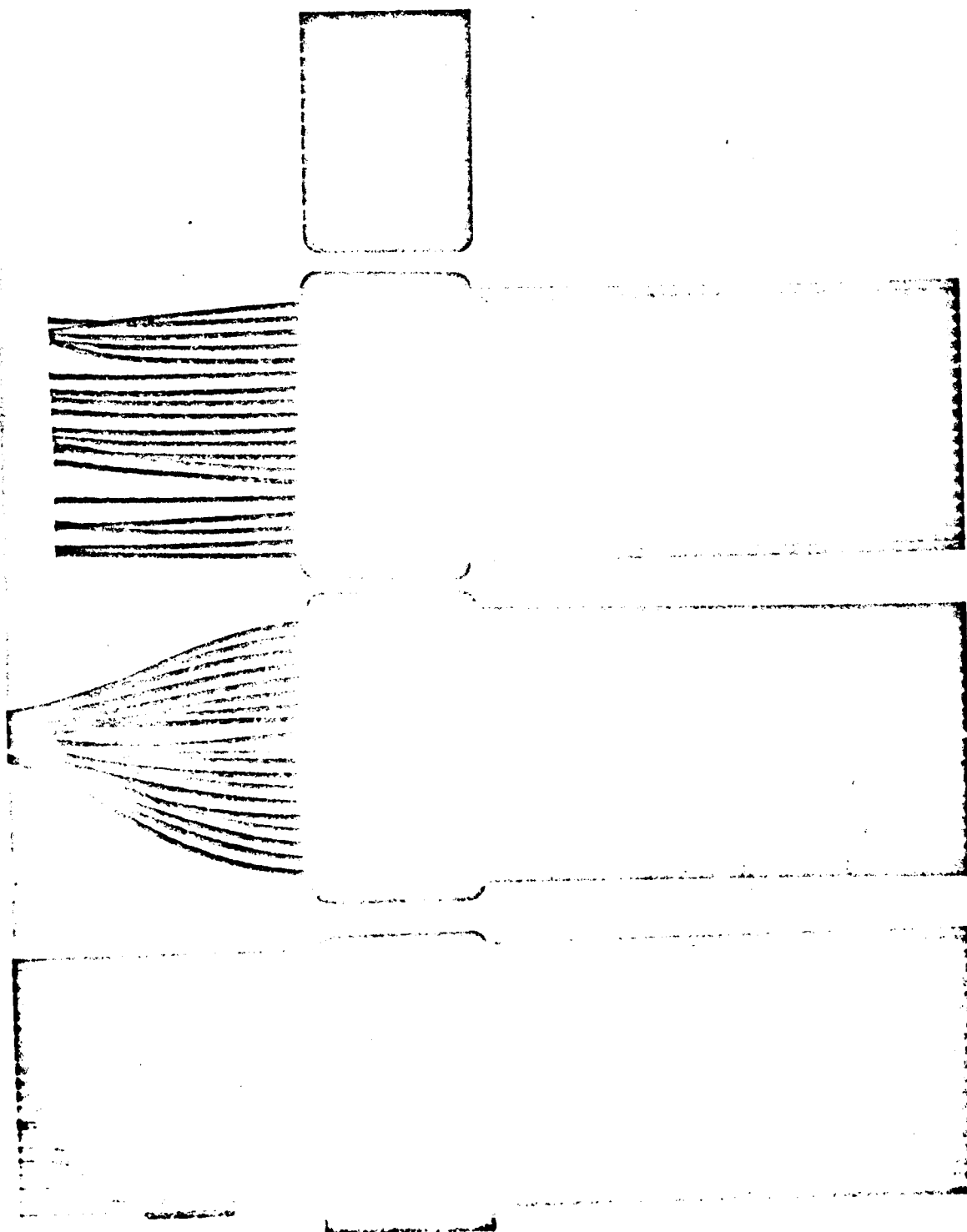


FIGURE B-3.—BOX TERMINATION SPLICES

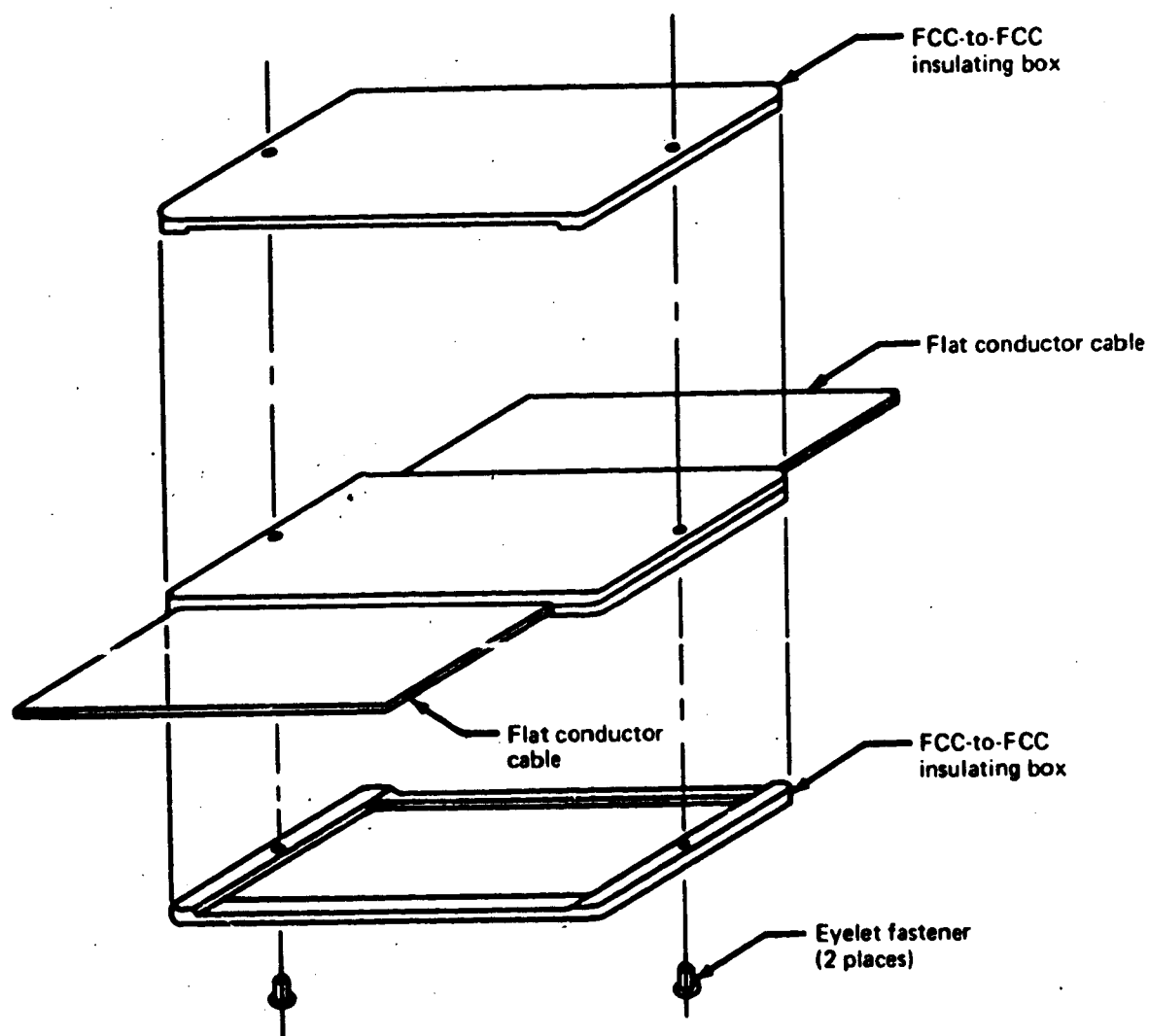


FIGURE B-4.—EXPLODED VIEW OF COMPONENTS—FCC TO FCC

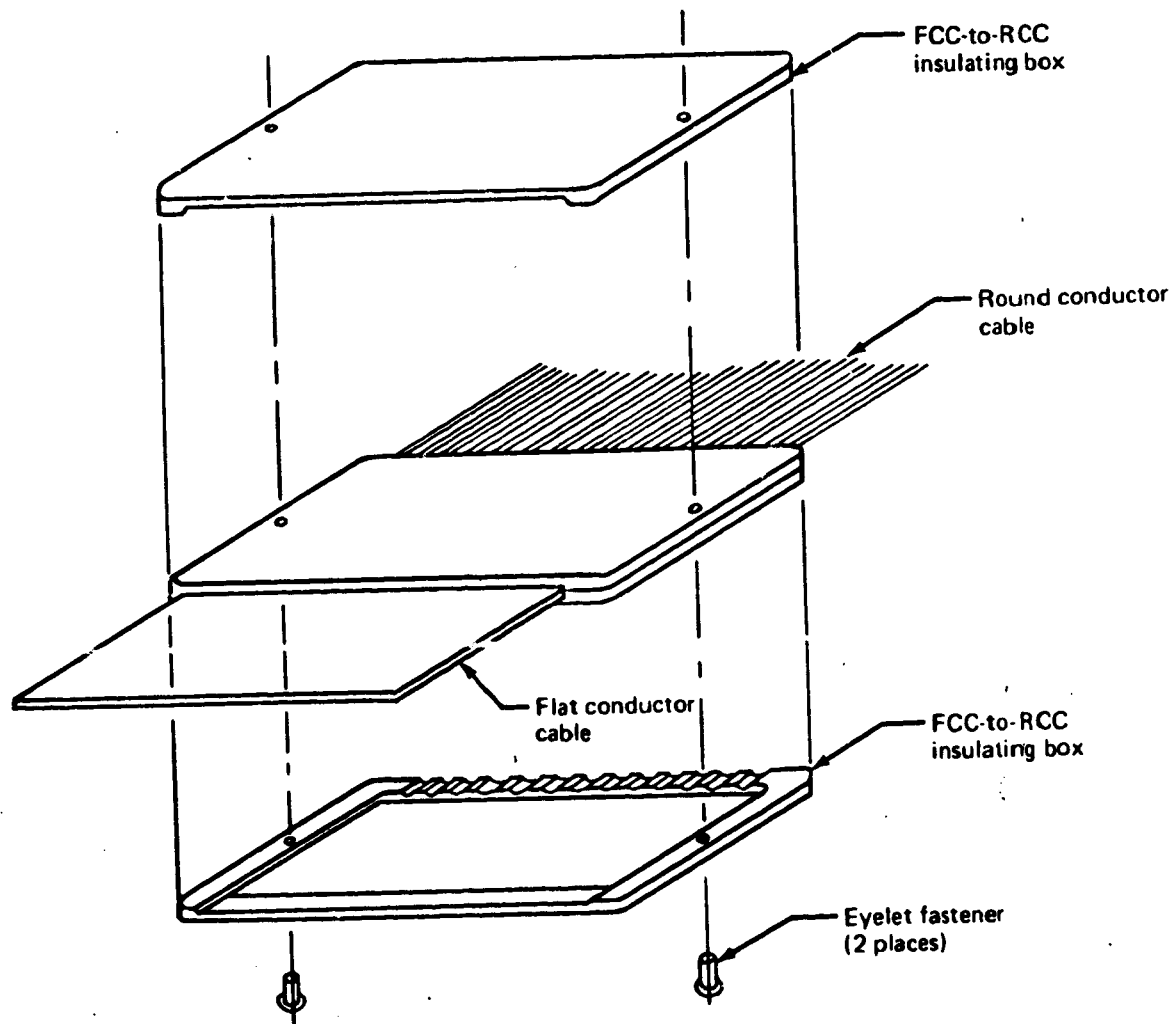


FIGURE B-5.—EXPLODED VIEW OF COMPONENTS—FCC TO RCC

TABLE B-1.—FCC-TO-FCC AND FCC-TO-RCC CABLE SPLICE COMBINATIONS AND TERMINATING HARDWARE

FCC-to-RCC wire or cable	Termination	Splice number
M555543/9A-19H4E	FCC to FCC	86770 A-MP, Inc.
M555543/9A-19H4E (FCC) M81044/10-24-9 (RCC)	FCC to RCC	86773 A-MP, Inc.

B.6.3 In-Process Corrections

In-process corrections would require removal of the splice area and repeating B.6.2.

B.7 QUALITY CONTROL

The quality Control Department shall maintain the necessary surveillance to ensure compliance with this specification and shall verify certification of all production crimping and stripping tools according to requirements of D2 6438.

APPENDIX C

PROCESS SPECIFICATION FOR TRANSITION SPLICE-MTSM

C.1 SCOPE

This specification establishes the requirements for terminating flat conductor cable (FCC) to flat conductor cable and flat conductor cable to round conductor cable (RCC) using the heat-recoverable multiple termination splice module (MTSM).

C.2 CLASSIFICATION

There is no classifications by types, classes, or grades for this specification.

C.3 REFERENCES

- a) BAC 5043 Preparation of Conductors and Terminals for Soldering

C.4 MATERIALS CONTROL

None

C.5 FACILITIES CONTROL

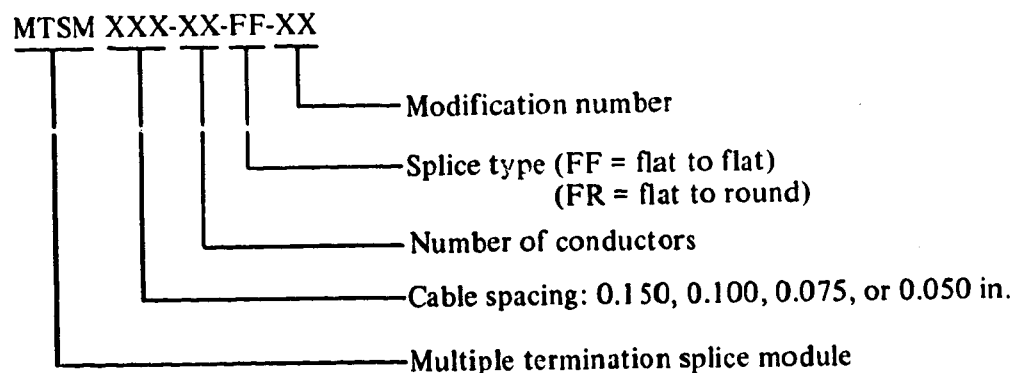
- a) Conductive heating tool for bench use with control unit
Model MTST-100
Raychem Corp.
- b) Platen assembly--FCC to FCC
Model MTST-101
Raychem Corp.
- c) Platen assembly--FCC to RCC
Model MTST-102
Raychem Corp.

- d) H-film flat cable stripper (cold blade)
NASA/MSFC PM-11307
- e) Round wire stripper
45-1610 for MIL-W-81044/16 wire
45-1611 for MIL-W-81044/12 wire
Ideal Industries

C.6 MANUFACTURING CONTROL

C.6.1 Part Numbering

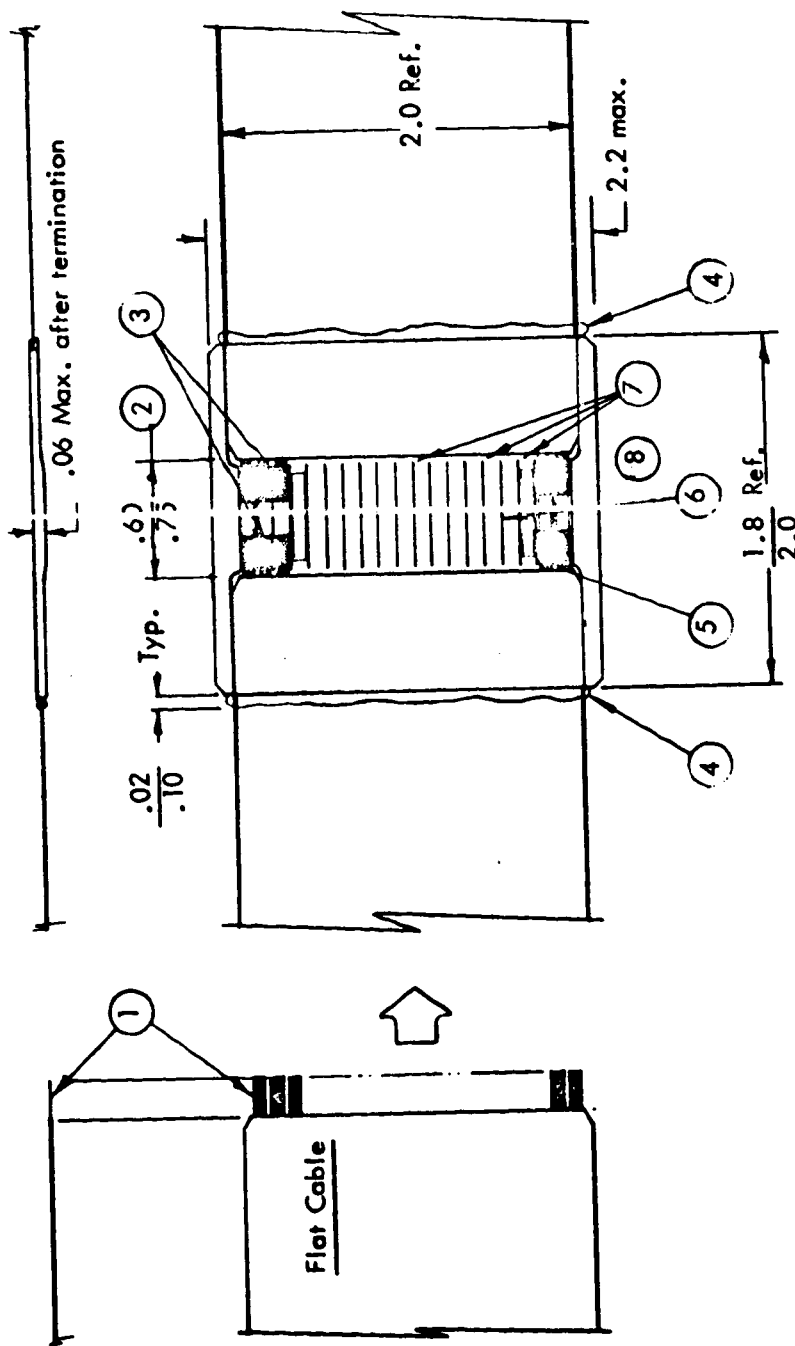
- a) Raychem splice part numbers are determined as follows:



- b) Typical Raychem splices are shown in figures C-1 and C-2

C.6.2 Preparing Tooling for Operation

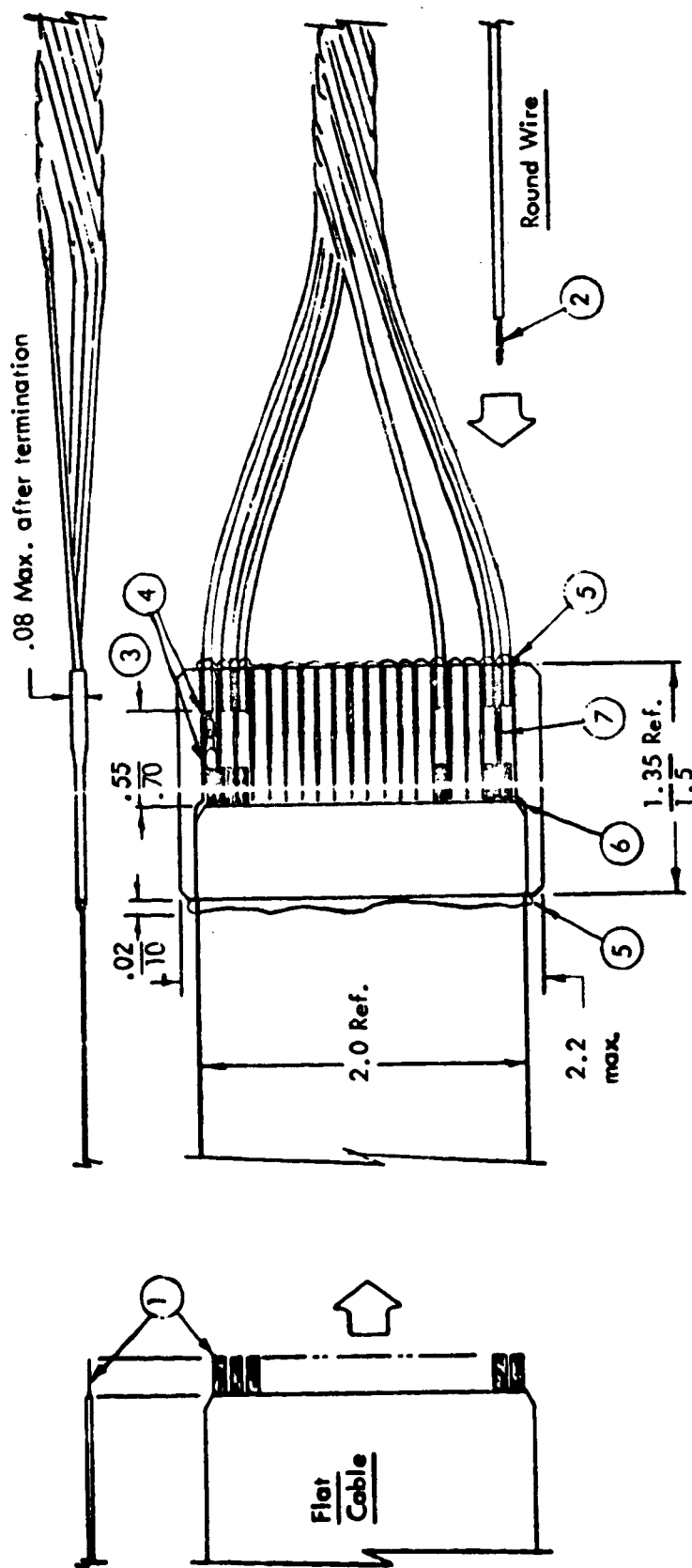
- a) Plug the two connectors from the heater into the receptacles on the rear of the control unit (C.5a). Attach the power cord from the control unit to a grounded 120 V, 60 Hz, ac source capable of supplying 6 amp. Open the heating jaws by turning the lever arm clockwise to the horizontal position. Move the red heating jaw assembly of the heater to the cooling position by pushing it down the guides as shown in figure C-3.



1. Stripped flat conductors must be straight, in line, free of nicks and on correct centers. (See Page 1).
2. Insulation of properly stripped cables may be separated within limits shown after termination.
3. Insert flat cables and center termination in platen assy. MTST-101 of Heating Tool MTST-100. Clamp each cable securely assuring that cable insulation is firmly inserted within MTSM. Clamp platen and start Heating Tool. Temperature and time are 510° F and 120 sec. respectively. See Application Procedure MTSP-100 for complete instructions.
4. Sealing material will flow out as shown.
5. Sealing material will pot space between conductors and partially fill each cavity. Bubbles or voids between conductors greater than .010 inch are not permitted.
6. When held up to strong light each bond separating conductors must be uniform in width and not partially or fully bridged by sharp corners, solder or flux.
7. All ends of bonds must be even with one another and intact along their entire lengths.
8. No evidence of burn-thrus or pin holes are allowable.

MTSM 100-19FF01

FIGURE C-1.-FCC-TO-FCC TRANSITION SPLICE-MTSM



1. Stripped flat conductors must be straight, in line, free of nicks and on correct centers. (See page 1).
2. Stripped round conductor must be straight and fully wrapped.
3. Insert flat cable and then all round wires desired. Center termination in platen assembly MTST-102 of Heating Tool MTST-100. Clamp cable and wires securely assuring that cable insulation is separated within dimensions shown. Clamp platen and start Heating Tool. Temperature and time should be 510° F and 120 sec. respectively. See Application Procedure MTSP-100 for construction instructions.
4. After termination solder should wet and filler between metal inserts and conductors.
5. Sealing material will flow out as shown. Empty wire sockets will automatically seal.
6. Sealing material will pot space between flat conductors. Bubbles smaller than .010 permitted if not contiguous.
7. When held up to strong light each bond separating conductors must be uniform in width and not partially or fully bridged by sharp corners, solder or flux.
8. All ends of bonds must be even with one another and intact along their entire lengths.
9. No evidence of burn-thrus or pin holes are allowable.

MTSM 100-19 FRO1

FIGURE C-2.-FCC-TO-RCC TRANSITION SPLICE-MTSM

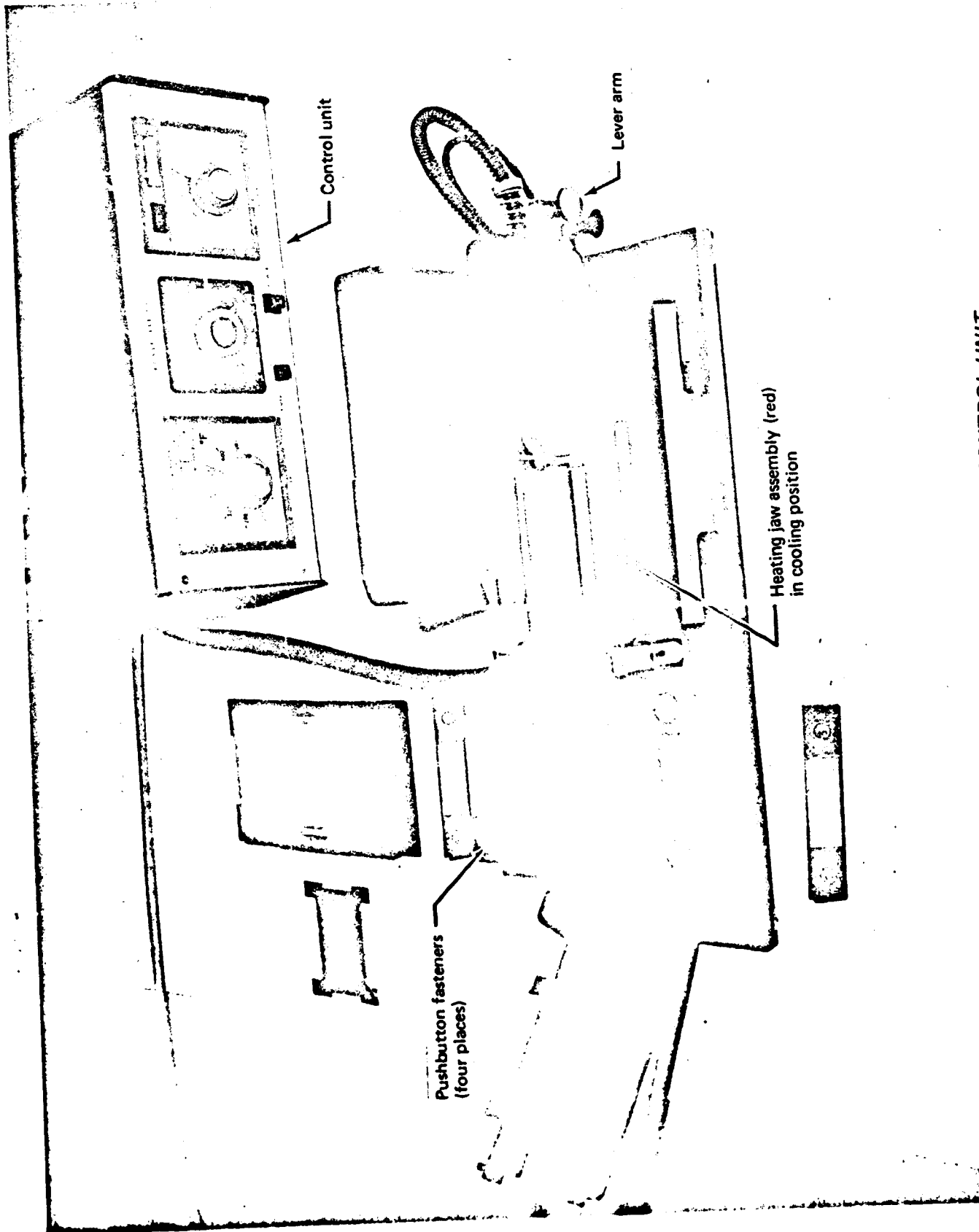


FIGURE C-3.—HEAT SHRINK TOOL AND CONTROL UNIT

- b) Select the proper platen assembly per table C-1 and place the studs of the four fasteners into their receptacles located in the top of the four support posts.

TABLE C-1.—TOOLING PREPARATION^a

Splice		Platen assembly number	Heating	
Type	Part number		Temperature, °F	Time, sec
FCC to FCC	MTSM 100-19FF01	MTST-101	510	120
FCC to RCC	MTSM 100-19FR01	MTST-102	510	120

^aThe platen assemblies are identified by number and type on the bottom side.

The top sides of the platen assemblies have red rubber pads for clamping the cable at each end. Either end may be placed toward the operator; however, in the case of platen assembly MTST-102 for FCC to RCC, place the RCC end with the spring wire-holding clamp toward the operator for ease of operation.

- c) Secure the platen assembly to the heater by depressing the four pushbutton fasteners until they lock down (fig. C-3).

NOTE: To remove a secured platen assembly, depress the four locked pushbutton fasteners to unlock.

The top platen of each assembly is a loose part and is not used until the assembled splice and cables are to be clamped for heating.

The two cable-holding clamps are loose parts and are used later.

- d) Turn the heater on by pressing the button marked "power" on the control unit. Adjust both of the temperature controllers and the timer to the values specified in table C-1.

NOTE: Allow approximately 20 min for the heating jaws to attain the specified temperature before using. The meter pointer of each controller will be in the center of the scale and the red indicator light will be cycling ON and OFF when the preset temperature has been reached.

CAUTION: Do not terminate MTSM splices until both heaters have reached their specified values.

C.6.3 Cable Preparation

Strip the ends of the FCC and/or the RCC to be terminated per figures C-1 and C-2 using tooling C.5d or C.5e. Remove all traces of the insulation leaving the conductor ends clean, bare, and free of oxides. Make sure all flat conductors are flat and straight and that the stranded round wire conductors are tightly twisted together.

NOTE: If the flat conductor cable or the individual round conductor wires are to be stripped prior to termination and stored in the stripped condition, pre-tin the conductors per BAC 5043.

C.6.4 Cable Splicing

C.6.4.1 Selecting Splice

Select the proper splice from table C-1.

C.6.4.2 Inserting Cables Into Splice

a) FCC to FCC

- 1) Insert the stripped FCC end into the splice making sure that each conductor enters into its individual cavity. A slight downward pressure on the flat cable during insertion will aid the process. The unstripped portion of the cable should butt against the stop built into the splice.
- 2) Repeat the above procedure to insert the second FCC into the opposite end of the splice.

b) FCC to RCC

- 1) Insert the FCC cable into the splice per C.6.4.2a.
- 2) Insert the individual stripped wires of the RCC into their assigned positions in the divided cavities of the splice. Insert each conductor with the insulation bottoming against the stop.

NOTE: Check to see that the insulation on all individual wires are inserted to the same depth and even.

C.6.4.3 Inserting Cable Splice Assemblies Into Heating tool

- a) Verify that the proper platen assembly per C.6.2b is mounted in the tool.

b) FCC to FCC

- 1) Place the cable splice into the platen assembly of the tool. Check to ensure that the FCC remains fully seated against the built-in stop.

- 2) Clamp the FCC to the platen assembly using the cable-holding clamps. Secure in place by depressing the pushbutton fasteners as shown in figure C-4.

c) FCC to RCC

- 1) Place the individual RCC wires in their respective positions in the spring wire-holding clip as shown in figure C-5. The wires should be straight, approximately parallel, and must not cross in the area between the spring clip and the splice. Check to ensure that each wire is positioned fully against its built-in stop in the splice.
- 2) Clamp the RCC to the platen assembly using the cable-holding clamp (fig. C-5).
- 3) Clamp the FCC side of the splice per C.6.4.3b.

C.6.4.4 Closing and Locking Top Platen

- a) Close the top platen onto the splice as shown in figure C-6.
 - 1) Make sure that the proper top platen is used for the type splice being made.
 - 2) When making FCC-to-RCC splices, install the top platen so that the RCC end of the splice fits into the cavities provided in the platen.

NOTE: One side of the platen is designed with a nonstick coating. Be sure that the nonstick coating side is in contact with the splice

- b) Lock each of the two pivoted arms that secure the top platen down against their stops using the catches provided (fig. C-6).

C.6.4.5 Heating Splice Assembly

- a) Set the timer on the control unit for the heating time required per table C-1.
- b) Move the heated jaws of the conductive-heating tool over the splice held by the top and bottom platens. Clamp the red heated jaws onto the platens by turning the lever arm counterclockwise from its horizontal to its vertical position (see fig. C-7).

NOTE: This automatically starts the timer.

REPRODUCIBILITY OF THE ORIGINAL PICTURE IS POOR.



FIGURE C4.-PLATEN ASSEMBLY-FCC-TO-FCC SPLICE

REPRODUCIBILITY OF THE ORIGINAL PHOTO IS POOR.

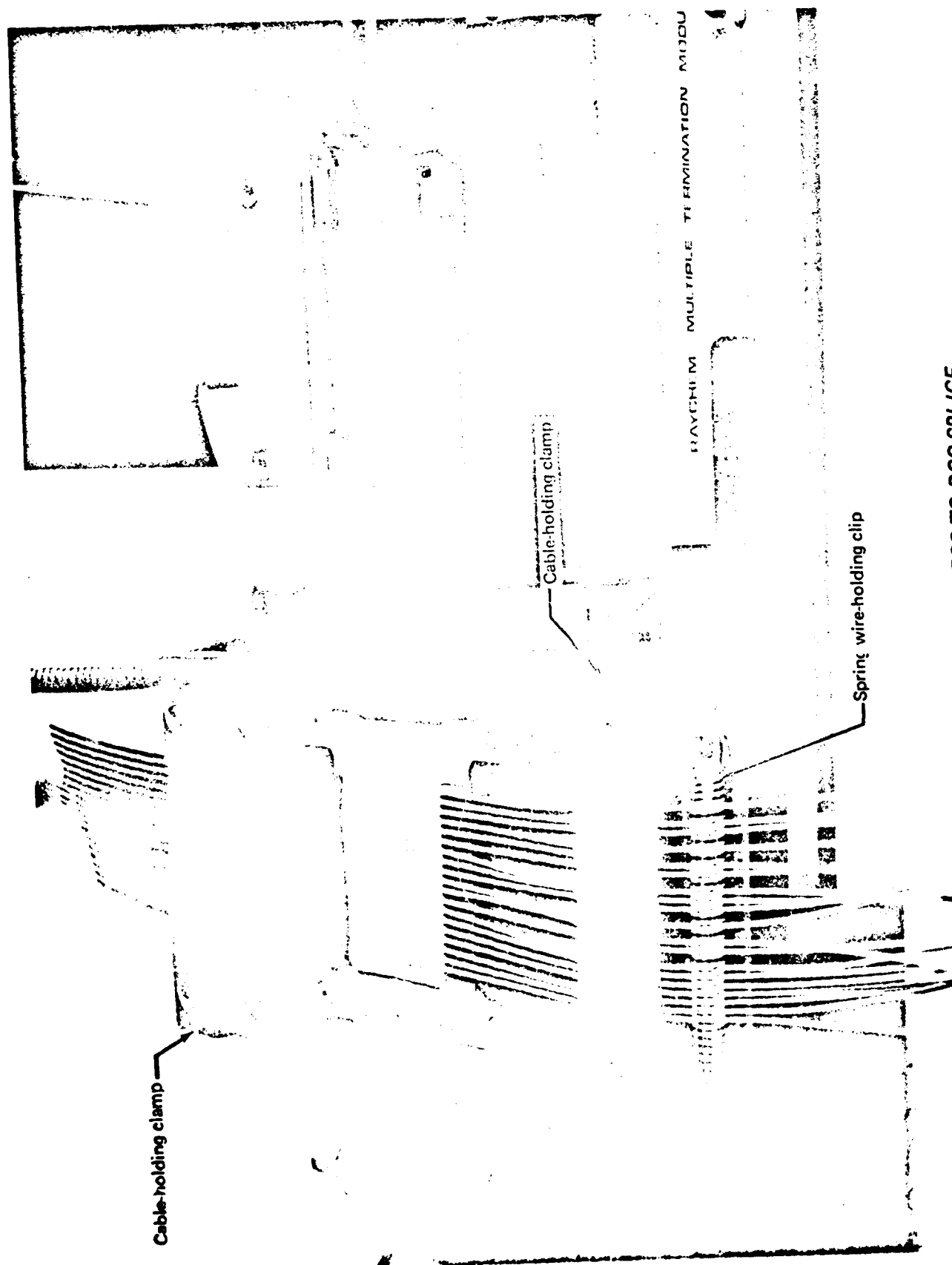


FIGURE C-5.—PLATEN ASSEMBLY—FCC-TO-RCC SPLICE

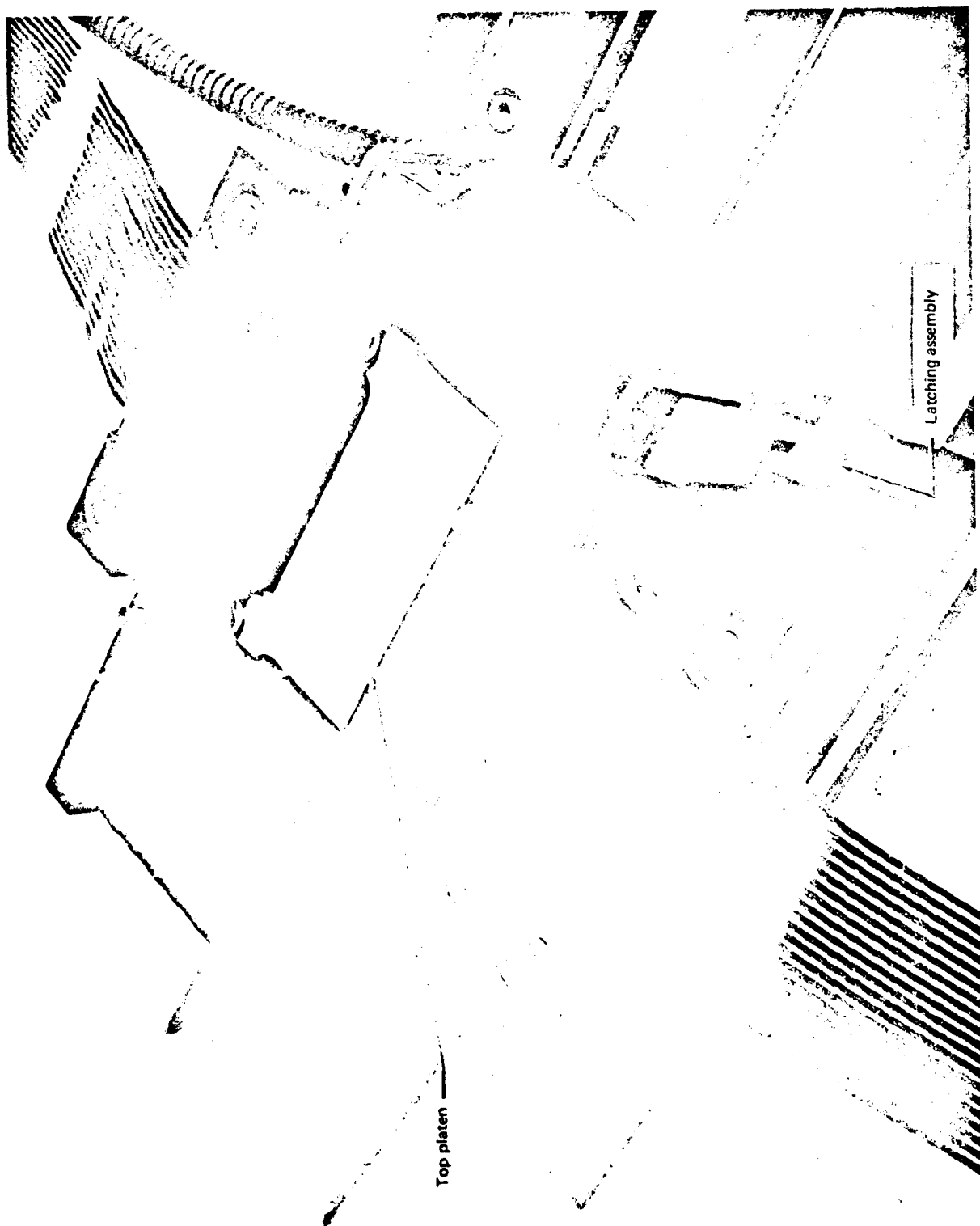


FIGURE C-6.—PLATEN ASSEMBLY—TOP PLATEN CLOSED

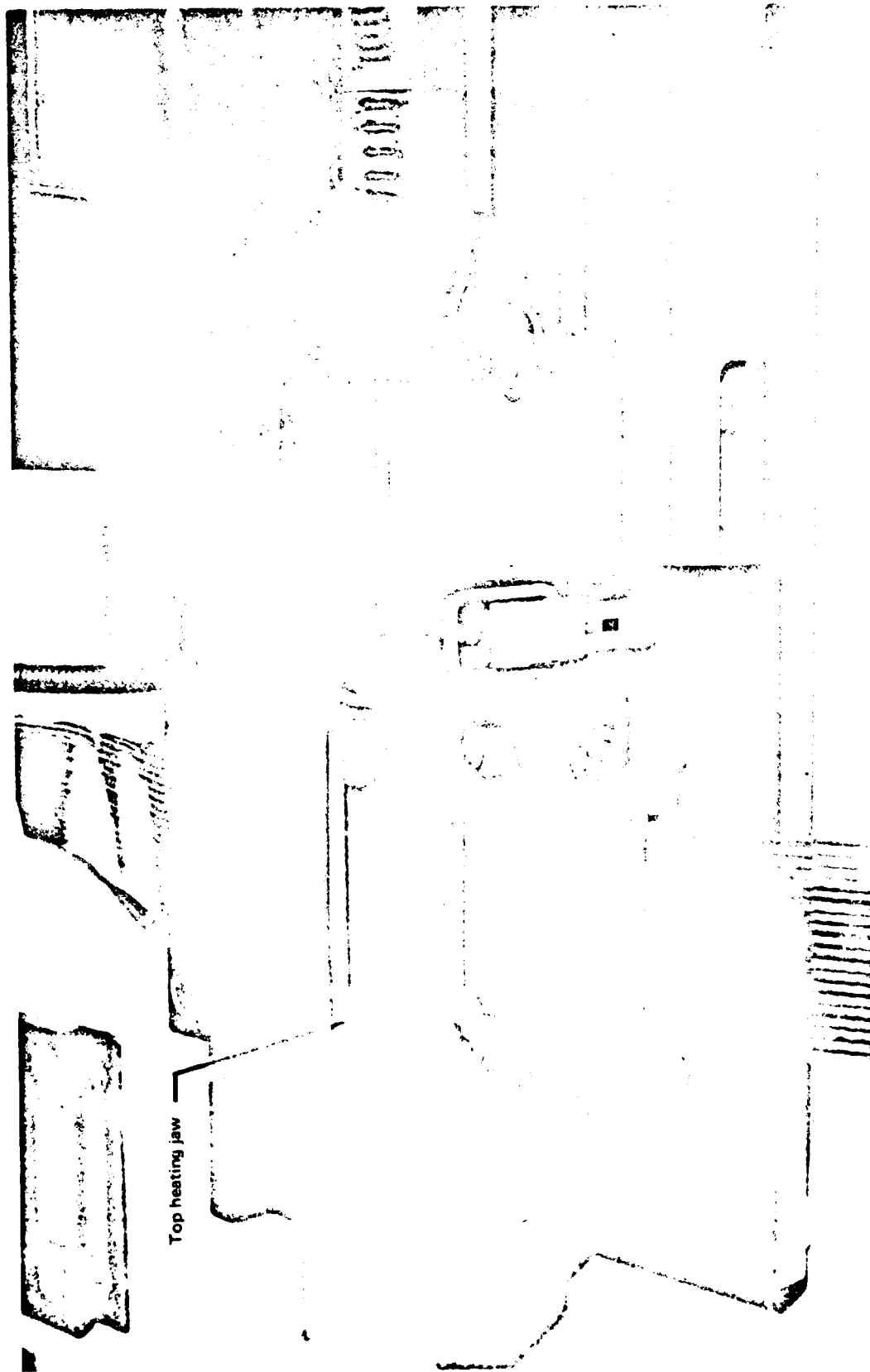


FIGURE C-7.—PLATEN ASSEMBLY.—HEATING JAWS IN POSITION ON SPLICE

- c) At the end of the heating time set on the timer, the control unit emits a continuous audible tone until the heat jaws are removed. When the audible tone sounds, immediately remove the heating jaws by returning the lever arm to its horizontal position and slowly sliding the jaw assembly to its cooling position.

CAUTION: Failure to promptly remove the heating jaws at the end of the heating cycle may overheat and damage the splice assembly.

C.6.4.6 Cooling and Removing Splice Assembly

- a) The cooling blower will start its automatically controlled cooling cycle when the heating jaws are returned to the cooling position.

NOTE: This must be done slowly per C.6.4.5c to allow the motor-driven timer to reset while the jaws are manually moved to the cooling position.

Do not disturb the splice or cables during the cooling cycle.

- b) At the end of the cooling cycle, a single audible tone will be emitted and the assembly may be removed.
- c) Unlock the top platen clamping arms by releasing the catches, swing back to the open position, and remove the top platen.
- d) Release the cable clamps by depressing the pushbutton fasteners and remove.
- e) Lift the completed splice from the heating tool.
- f) Completed cable and splice assemblies are shown in figures C-8 and C-9.

C.6.5 In-Process Correction

- a) This procedure is applicable only in cases of underheating the part.
- b) An underheated part may display partial rather than full recovery, poor solder joints (bad fillets or solder not completely melted), or inadequate flow of meltable sealing material.
- c) To correct this condition, the assembly may be placed in the heating tool and reheated per C.6.4.3 through C.6.4.6 above.

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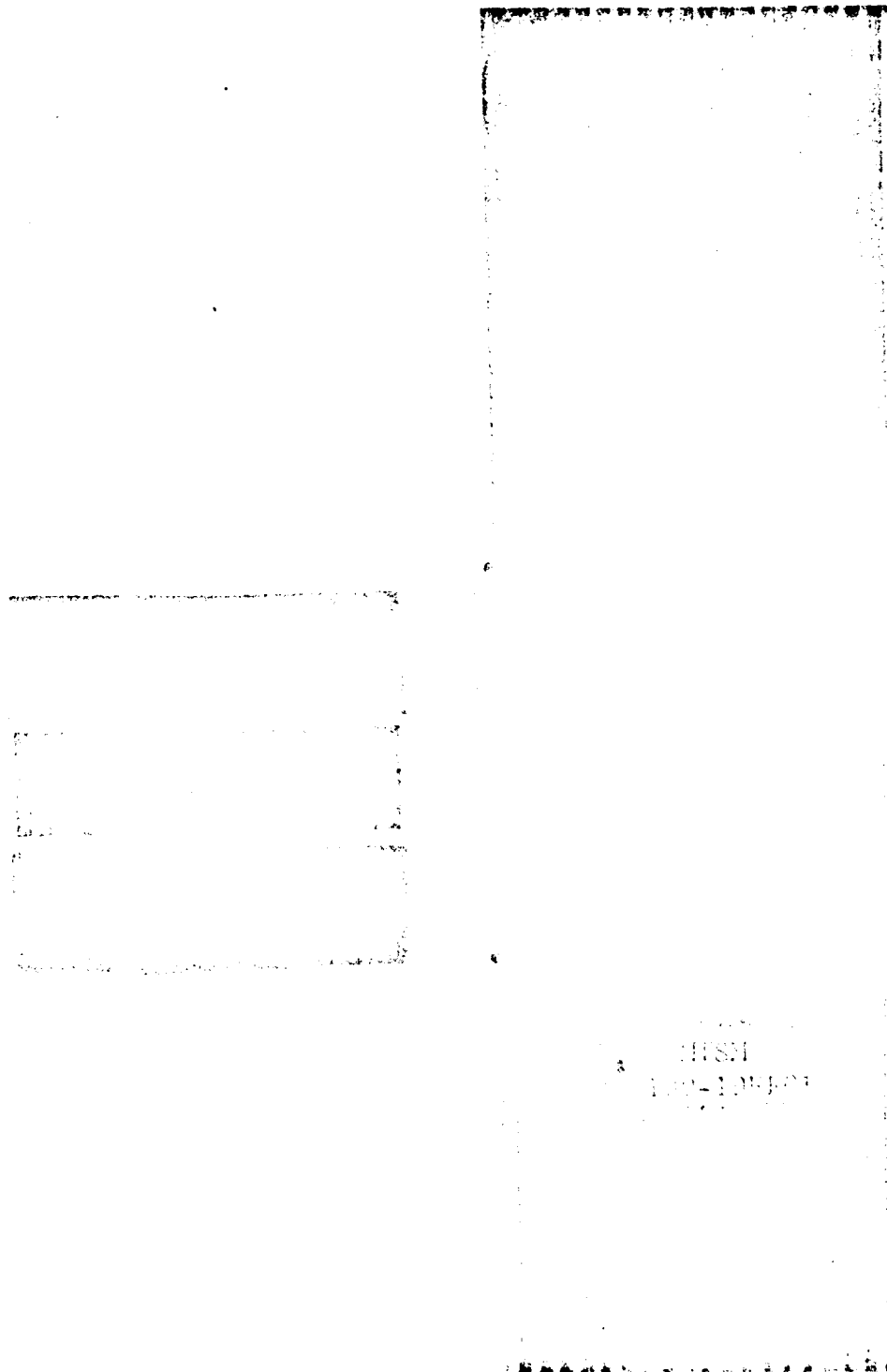


FIGURE C-8.—COMPLETED FCC-TO-FCC SPLICE

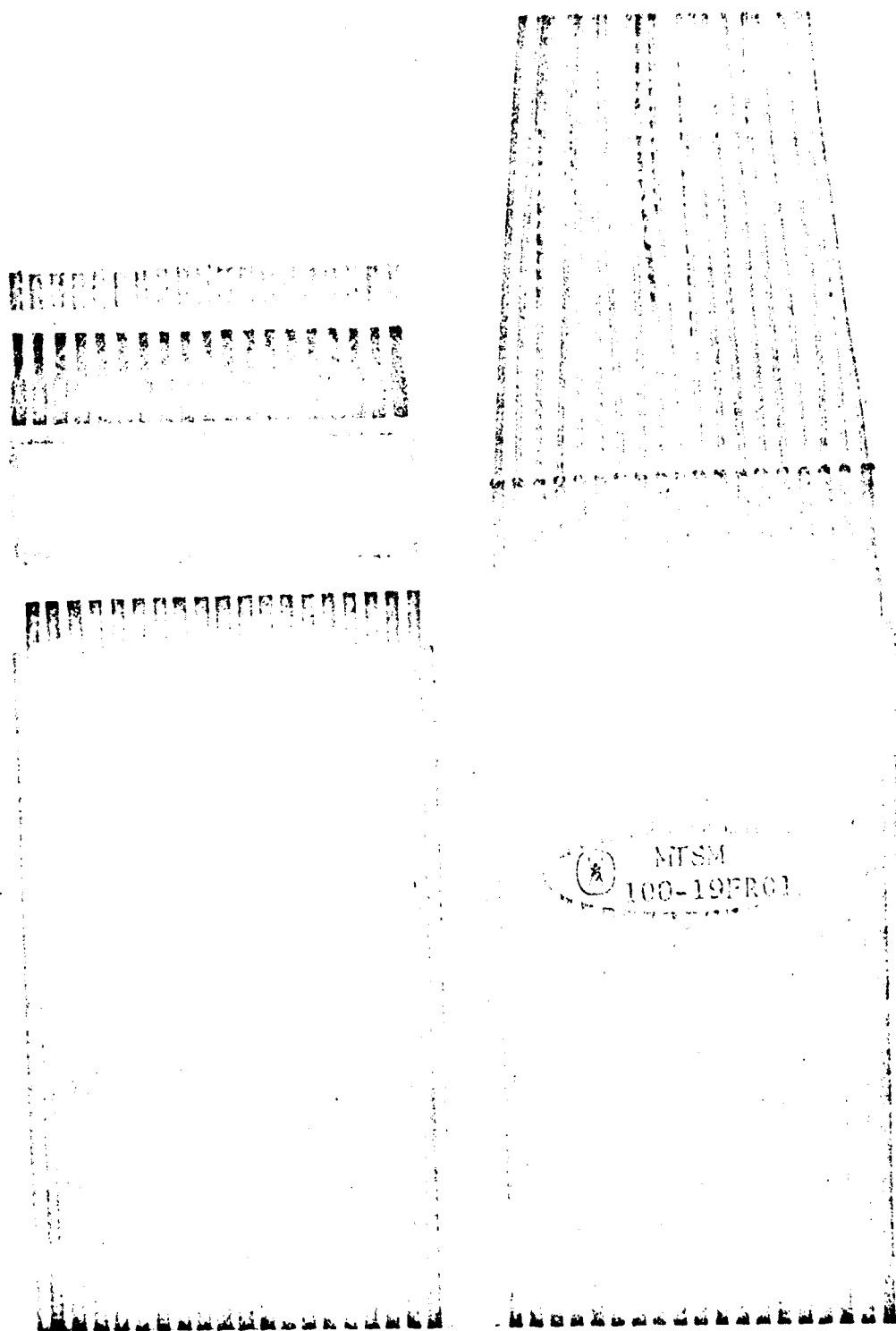


FIGURE C-9.—COMPLETED FCC-TO-RCC SPLICE

C.7 QUALITY CONTROL

- a) Quality Control shall ensure conformance with the requirements of this specification.
- b) Quality Control shall visually inspect splice assemblies, on a surveillance basis, for the following conditions:
 - 1) The body of the splice shall be fully recovered to a flat condition conforming to the flat cable surfaces and surrounding the metal inserts.
 - 2) Each conductor of both FCC and RCC shall be overlapped and soldered to the metal inserts in the splice as evidenced by the fillets of solder joining the conductors to the metal inserts.
 - 3) There shall be no solder outside of the tubular individually bonded area.
 - 4) The sealing material shall have been thoroughly heated as evidenced by having lost its original configuration. It should conform to the splice interstices and seal the terminated ends. Bubbles smaller than 0.015 in. in diameter are permissible if not contiguous. It is permissible for some of the sealing material to come out the ends of the splice. Some sealing material present around the metal inserts is acceptable if the solder joints are sound per item 2 above.
 - 5) There shall be no evidence of tearing or puncture of the insulating body of the splice.
- c) Failure to meet any of the above requirements shall be cause for rejection.

APPENDIX D

TEST PLAN AND EVALUATION REQUIREMENTS FOR LOW-PROFILE CONNECTING DEVICE AND PERMANENT SPLICE

D.1 PURPOSE

This plan establishes the methods for evaluation testing of both FCC-to-FCC and FCC-to-RCC permanent splices and low-profile connecting devices.

The hardware will be fabricated in accordance with procedures and engineering drawings with sufficient details to ensure control and repeatability of production.

D.2 SCOPE

This plan includes test methods, conditions, limitations, equipment list, and test parameters required for performing evaluation testing.

D.3 REFERENCES

- a) MIL-C-55543 Cable, Electrical, Flat, Flexible Conductor
- b) MIL-T-7928 Terminal Lugs, Splices, Conductors; Crimp Style, Copper, General Specification For
- c) MIL-STD-202 Test Methods for Electrical and Electronics Components
- d) MIL-STD-810 Environmental Test Methods
- e) FTMS 228 Cable and Wire, Insulated; Methods of Testing (Federal Test Method Standard)

D.4 RESPONSIBILITIES

The Electrical Technology group of The Boeing Company will be responsible for testing and documentation of test details and results.

D.5 TEST DOCUMENTATION

All pertinent test data and analyses will be compiled and will be included in the documentation stipulated by the contract.

D.6 PROCEDURES

D.6.1 Test Equipment

The test equipment used in this test program will have been certified and calibrated within 90 days prior to performing all specified tests.

D.6.2 List of Equipment

Equipment to be used is included in each test procedure.

D.6.3 Test Conditions and General Environments

Unless otherwise specified, tests will be conducted at room ambient pressure, temperature, and relative humidity per general conditions of MIL-STD-202.

D.6.4 Pretest Requirement

D.6.4.1 Examination of Test Samples

The permanent splices and low-profile connecting devices will be inspected visually and anomalies recorded. This inspection will be repeated at the conclusion of the environmental exposure.

D.6.4.2 Preparation of Test Hardware

The test samples will be prepared in conformance with the applicable drawings. All test hardware will be identified and coded. A minimum of 10 permanent splices per concept and seven low-profile connecting devices will be submitted for test.

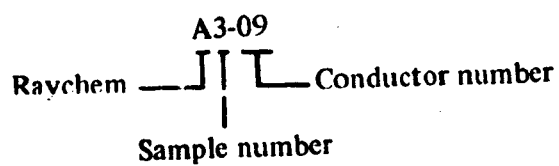
D.6.4.3 Specimen Identification

Identification will be per table D-1.

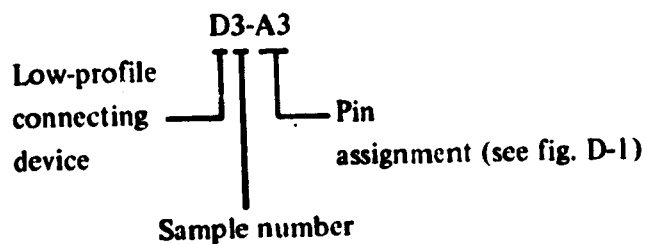
TABLE D-1.—SPECIMEN IDENTIFICATION

	Group	Type	Sample number
Permanent splices	A	Raychem shrinkable sleeve and solder pak	
		FCC to FCC	1 to 10
	B	FCC to RCC	21 to 30
		A-MP crimp-through insulation	
Low-profile devices	D	FCC to FCC	1 to 10
		FCC to RCC	21 to 30
		Low-profile connecting device	1 to 7

A typical part number for a permanent splice will be determined as follows:



A typical part number for a low-profile connecting device will be determined as follows:



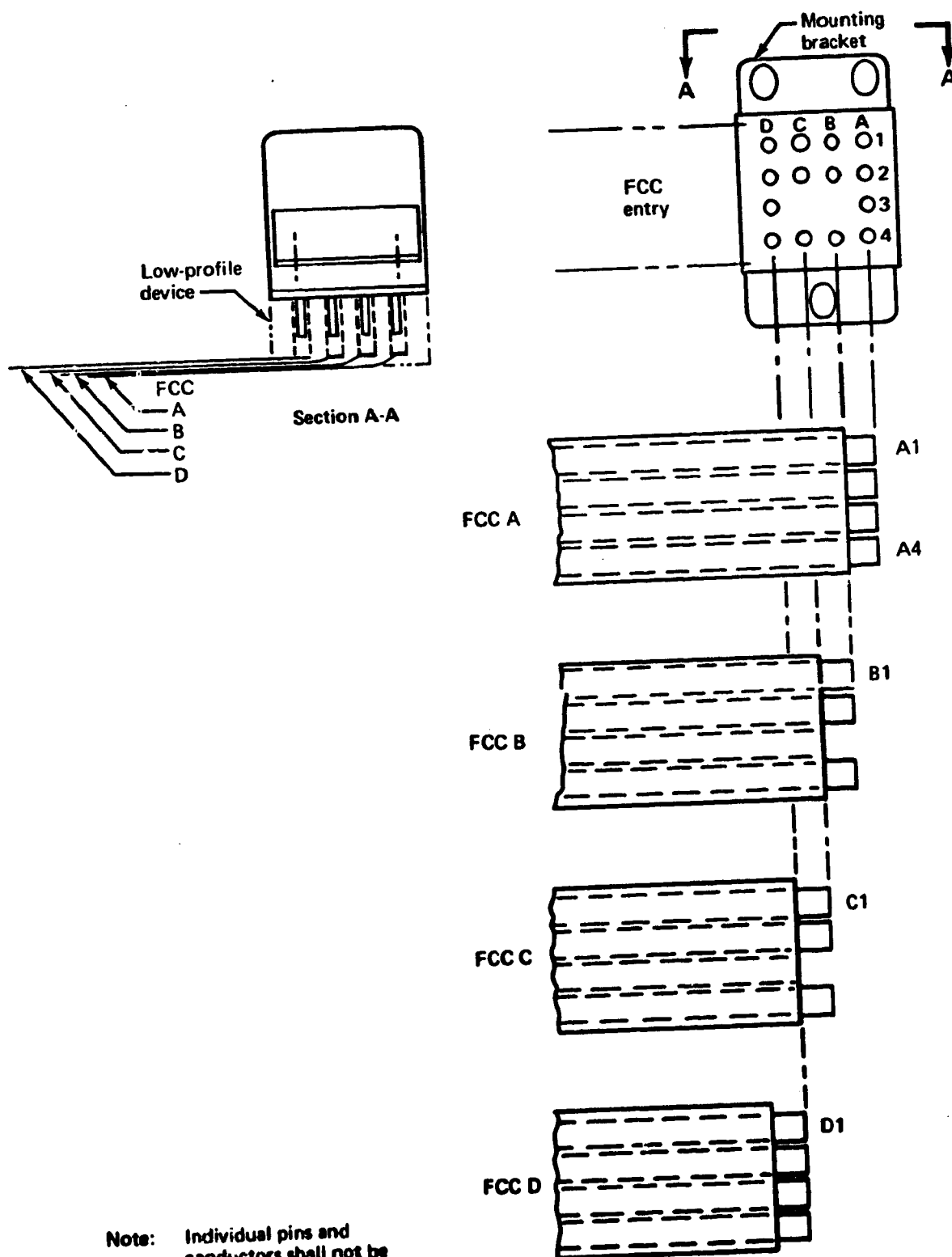


FIGURE D-1.—PIN ASSIGNMENT—TYPICAL LOW-PROFILE CONNECTING DEVICE

D.6.4.4 Specimen Description

The following items are described in detail for reference.

FCC.—FCC is flat conductor cable to MIL-C-55543/9A-H4E19. It is a 2-in. wide cable with 19 conductors at 0.1-in. centers insulated with 3-mil FEP (primary) and 1-mil Kapton (secondary). Conductors are of ETP unplated copper formed by rolling round wire. Conductor dimensions are 0.004 by 0.065 in. (AWG 25).

RCC.—RCC is AWG 24 round conductor cable of 19 by 36, silver-plated, high-strength copper alloy construction with 10-mil crosslinked polyalkene insulation per MIL-W-81044/16.

Splice area, concept 1.—For FCC-to-FCC splices, A-MP crip-through insulation, soldered tabs are cut and joined together by welding. For FCC-to-RCC, solder tabs and socket contacts are soldered to form the transition. Insulation for both types consists of two box halves made of diallyl phthalate and filled with Sylgard sealant.

Low-profile device.—The device consists of a glass/silicone case and cover with socket contacts press fit into the case face in a pattern to match that of the mating relay. The case is filled with Sylgard 184 sealant after being terminated to the flat conductor cable.

D.6.4.5 Disposition of Samples

Disposition of samples after test will be per table D-2.

TABLE D-2.—SAMPLE DISPOSITION^a

Type	Sample									
	1	2	3	4	5	6	7	8	9	10
Permanent splices FCC to FCC and FCC to RCC	N	N	B	B	N	N	B	N	B	B
Low-profile connecting devices	B	B	N	N	N	N	N	—	—	—

^aN = NASA

B = Boeing, further testing

D.6.4.6 Test Sequence

The sequence shown in tables D-3 and D-4 will be followed for testing the permanent splices, and the sequence of table D-5 will be followed for testing the low-profile connecting devices.

D.6.5 Test Methods and Procedures

D.6.5.1 Visual and Dimensional Examination

The test samples will be inspected visually and a record made of sample dimensions, construction, and color. After completion of testing, items will be visually inspected and any deterioration or damage resulting from test will be recorded.

D.6.5.2 Insulation Resistance

Procedure.—The insulation resistance will be measured with a megohmmeter. After 15-min warmup, measurements will be made as follows:

- a) Apply 500 Vdc between each conductor and its adjacent conductors by connecting odd-numbered wires to one potential lead and even-numbered wires, one at a time, to the other lead. This applies to both FCC and RCC.
- b) Allow the readings to stabilize for a maximum of 1 min.
- c) Record the insulation resistance reading.

Requirements.—Insulation resistance shall be greater than 500 M Ω for splices and 1000 M Ω for low-profile devices.

D.6.5.3 Dielectric Withstand Voltage (DWV)

Procedure.—Dielectric withstand voltage will be measured with a Hypot ac meter, as supplied by AiResearch. The following procedure will be used:

- a) Apply potential between each wire and all other wires.
- b) Apply a test voltage of 1500 V (1250 V for low-profile devices), 60 Hz at a rate of increase of 500 V per second
- c) Maintain the test voltage for 1 min.

TABLE D-3.—TEST SEQUENCE FOR BOX CONCEPT PERMANENT SPLICE EVALUATION

Test	Section	Test samples									
		FCC-to-FCC splices					FCC-to-RCC splices				
		1	2	3	4	5	6	7	8	9	10
<u>Initial</u>		X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
Visual and dimensional	D.6.5.1	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
Electrical continuity	D.6.5.4	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
Voltage drop	D.6.5.5	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
Dielectric withstand voltage	D.6.5.3	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
Insulation resistance	D.6.5.2	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
<u>Thermal shock</u>		X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
Electrical continuity	D.6.5.6	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
Voltage drop	D.6.5.4	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
Dielectric withstand voltage	D.6.5.5	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
Insulation resistance	D.6.5.3	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
	D.6.5.2	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
<u>Thermal aging</u>		X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
Electrical continuity	D.6.5.7	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
Voltage drop	D.6.5.4	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
Dielectric withstand voltage	D.6.5.5	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
Insulation resistance	D.6.5.3	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
	D.6.5.2	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
<u>Moisture resistance</u>		X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
Electrical continuity	D.6.5.9	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
Voltage drop	D.6.5.4	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
Dielectric withstand voltage	D.6.5.5	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
Insulation resistance	D.6.5.3	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
	D.6.5.2	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
<u>Salt fog</u>		X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
Electrical continuity	D.6.5.10	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
Voltage drop	D.6.5.4	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
Dielectric withstand voltage	D.6.5.5	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
Insulation resistance	D.6.5.3	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X
	D.6.5.2	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X	X X X X X

TABLE D-4.-TEST SEQUENCE FOR MTSM CONCEPT PERMANENT SPLICE

		Test samples																			
		FCC-to-FCC splices										FCC-to-RCC splices									
Test	Section	1	2	3	4	5	6	7	8	9	10	21	22	23	24	25	26	27	28	29	30
<u>Initial</u>		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Visual and dimensional	D.6.5.1																				
Electrical continuity	D.6.5.4																				
Voltage drop	D.6.5.5																				
Dielectric withstand voltage	D.6.5.3																				
Insulation resistance	D.6.5.2																				
<u>Thermal shock</u>																					
Electrical continuity	D.6.5.6																				
Voltage drop	D.6.5.4																				
Dielectric withstand voltage	D.6.5.5																				
Insulation resistance	D.6.5.3																				
	D.6.5.2																				
<u>Thermal aging</u>																					
Electrical continuity	D.6.5.7																				
Voltage drop	D.6.5.4																				
Dielectric withstand voltage	D.6.5.5																				
Insulation resistance	D.6.5.3																				
	D.6.5.2																				
<u>Moisture resistance</u>																					
Electrical continuity	D.6.5.9																				
Voltage drop	D.6.5.4																				
Dielectric withstand voltage	D.6.5.5																				
Insulation resistance	D.6.5.3																				
	D.6.5.2																				
<u>Salt fog</u>																					
Electrical continuity	D.6.5.10																				
Voltage drop	D.6.5.4																				
Dielectric withstand voltage	D.6.5.5																				
Insulation resistance	D.6.5.3																				
	D.6.5.2																				

TABLE D-5.—TEST SEQUENCE FOR LOW-PROFILE CONNECTING DEVICE EVALUATION

Test	Section	Test samples							
		1	2	3	4	5	6	7	8
Initial									
Electrical continuity	D.6.5.4	X	X	X	X	X	X	X	X
Voltage drop	D.6.5.5	X	X	X	X	X	X	X	X
Dielectric withstand voltage	D.6.5.3	X	X	X	X	X	X	X	X
Insulation resistance	D.6.5.2	X	X	X	X	X	X	X	X
Thermal shock	D.6.5.6	X	X	X	X	X	X	X	X
Electrical continuity	D.6.5.4	X	X	X	X	X	X	X	X
Voltage drop	D.6.5.5	X	X	X	X	X	X	X	X
Dielectric withstand voltage	D.6.5.3	X	X	X	X	X	X	X	X
Insulation resistance	D.6.5.2	X	X	X	X	X	X	X	X
Vibration	D.6.5.8		X	X	X				
Electrical continuity	D.6.5.4		X	X	X				
Voltage drop	D.6.5.5		X	X	X				
Dielectric withstand voltage	D.6.5.3		X	X	X				
Insulation resistance	D.6.5.2		X	X	X				
Thermal aging	D.6.5.7	X	X	X	X	X	X		
Electrical continuity	D.6.5.4	X	X	X	X	X	X		
Voltage drop	D.6.5.5	X	X	X	X	X	X		
Dielectric withstand voltage	D.6.5.3	X	X	X	X	X	X		
Insulation resistance	D.6.5.2	X	X	X	X	X	X		
Moisture resistance	D.6.5.9	X	X	X	X	X	X		
Electrical continuity	D.6.5.4	X	X	X	X	X	X		
Voltage drop	D.6.5.5	X	X	X	X	X	X		
Dielectric withstand voltage	D.6.5.3	X	X	X	X	X	X		
Insulation resistance	D.6.5.2	X	X	X	X	X	X		
Salt fog	D.6.5.10	X	X	X	X	X	X		X
Electrical continuity	D.6.5.4	X	X	X	X	X	X		X
Voltage drop	D.6.5.5	X	X	X		X	X		X
Dielectric withstand voltage	D.6.5.3	X	X	X		X	X		X
Insulation resistance	D.6.5.2	X	X	X		X	X		X

- d) While the voltage is applied, observe for any evidence of dielectric breakdown or flashover.
- e) Decrease voltage at 500 V per second.
- f) Maximum 2 mA leakage current allowed.

Requirements.—Samples shall show no evidence of dielectric breakdown and/or flashover.

D.6.5.4 Continuity Check

Procedure.—The continuity check will be made with a Simpson multimeter to ensure correct pin assignment. A 100% check shall be conducted.

D.6.5.5 Millivolt Drop

Procedure.—At least 20% of the conductors in each splice will be measured for millivolt drop. The test current will be 3 amp dc for the permanent splices and 5 amp dc for the low-profile devices. After the samples have reached thermal stability, the voltage drop across splices and device contacts will be determined. Sensing of the splice transition will be as shown in figure D-2.

Requirements.—A low millivolt drop across each junction is the desired goal. However, evaluation shall be based on junction resistance stability throughout the test. Basically, the junction will be compared with an equal length of the FCC to determine comparative millivolt drop.

D.6.5.6 Thermal Shock

Procedure.—The applicable samples will be subjected to five continuous cycles at $-55^{\circ} \pm 5^{\circ}\text{C}$ and $125^{\circ} \pm 2^{\circ}\text{C}$ for the splices of concept 1 (MTSM), $-55^{\circ} \pm 5^{\circ}\text{C}$ and $135^{\circ} \pm 2^{\circ}\text{C}$ for splices of concept 3, and $-55^{\circ} \pm 5^{\circ}\text{C}$ and $125^{\circ} \pm 2^{\circ}\text{C}$ for the low-profile connecting devices. The samples will be maintained at each temperature extreme for a minimum of 30 min. A maximum of 2 min. will be allowed for transfer between test chambers. After completion of the fifth cycle, the specimens will be removed from the test chambers and allowed to stabilize at room temperature.

Requirements.—DWV requirements shall be met. There shall be no visible evidence of damage to the splice material in addition to the voltage drop requirement per D.6.5.5.

D.6.5.7. Thermal Aging

Procedure.—The applicable samples will be placed in a circulating air oven stabilized at $125^{\circ} \pm 2^{\circ}\text{C}$ for the splices of concept 1 (MSTM), at $135^{\circ} \pm 2^{\circ}\text{C}$ for concept 3, and at $125^{\circ} \pm 2^{\circ}\text{C}$ for the low-profile

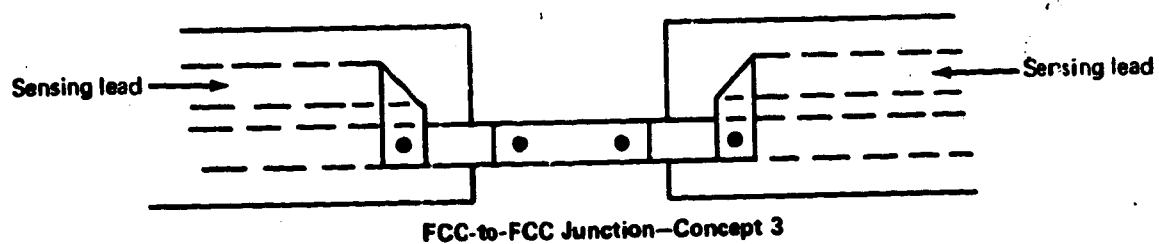
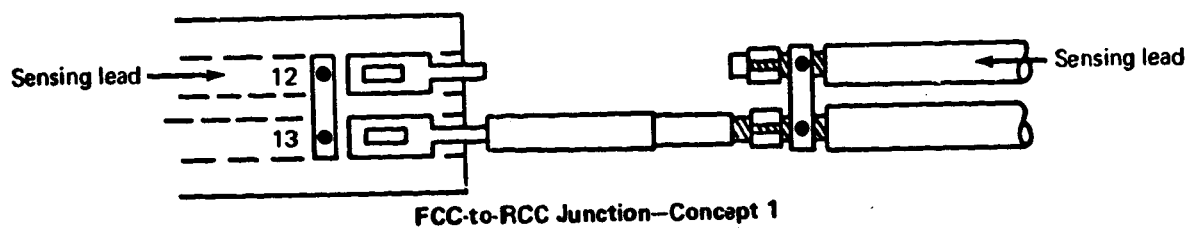
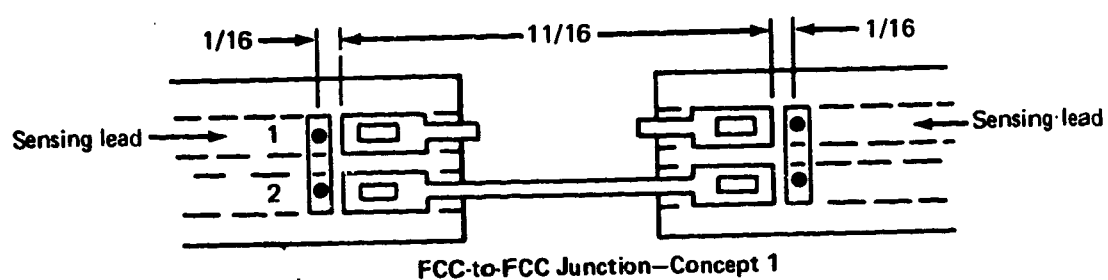


FIGURE D-2.—MVD SENSING

connecting devices. Samples will be subjected to these temperatures for 96 hr and then removed from the oven and allowed to stabilize at room temperature.

Requirements.—The insulation resistance, measured at the completion of test, shall not be less than 5000 M Ω for the splices and 1000 M Ω for the low-profile connecting devices.

D.6.5.8 Vibration

Procedure.—The applicable samples will be secured (with some splice samples stacked in groups of three and five) to a test fixture and mounted to the vibration exciter. Wire bundles will be clamped to nonvibrating points at least 8 in. from the splices or connecting devices. Accelerometers will be mounted on top of the test fixture near splices and devices to monitor vibration. The vibration will be random and the planes of vibration mutually perpendicular to each other.

The samples will be subjected to random vibration for not less than 1 hr per axis, as follows: acceleration spectral density increasing at a rate of 3 dB/octave from 20 to 200 Hz; constant at 0.06 g²/Hz from 200 to 1200 Hz, and decreasing at a rate of 3 dB/octave from 1200 to 2000 Hz.

Requirements.—Any structural or mechanical damage shall be noted and recorded. Also, all circuits shall be monitored in series with a continuity detector for interruption of circuits exceeding 1 μ sec.

D.6.5.9 Moisture Resistance

Procedure.—Test samples will be checked for moisture resistance as follows:

- a) Stripped wire ends will be sealed against moisture.
- b) The samples will then be mounted in the humidity chamber (Blue M) in a horizontal position with the tail wires entering the seals from the horizontal plane and no drip loops in the wires.
- c) The humidity chamber will be cycled as illustrated in figure D-3.
- d) Upon completion of five cycles, final measurements of insulation resistance and DWV will be made within 1 to 2 hr.

Requirements.—The insulation resistance, when measured at the completion of the test, shall not be less than 500 M Ω for the splices and 100 M Ω for the low-profile connecting devices.

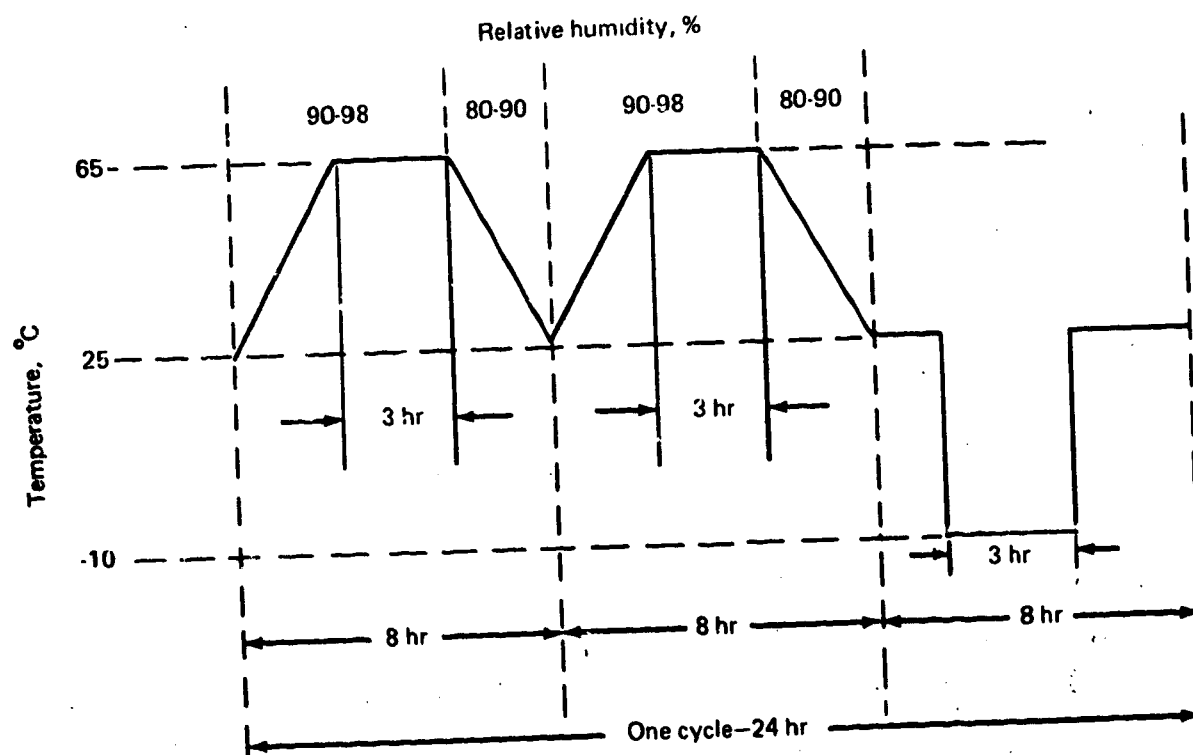


FIGURE D-3.-HUMIDITY CHAMBER CYCLES

D.6.5.10 Salt Fog

Procedure.—Test samples will be checked for salt fog resistance as follows:

- a) A salt solution, 5% by weight, will be prepared using distilled water and sodium chloride (NaCl).
- b) Applicable samples will be subjected to salt fog for a period of 48 hr.
- c) Following the 48-hr exposure, samples will be washed in flowing tap water.
- d) Salt deposits will be removed by use of a plastic bristle brush.
- e) Samples will then be dried at 35°C in a circulating air oven for a period of 12 hr.
- f) Samples will be examined and all observations and results recorded.
- g) IR and DWV will be measured and recorded.

Requirements.—There shall be no evidence of damage detrimental to the function of the samples. The insulation resistance shall be as for D.6.5.9.

D.6.5.11 Heat-Age Current Cycling

Procedure.—Test samples will be cycled for heat aging as follows:

- a) A convection-type oven will be turned on and set for 125°C.
- b) After the oven has stabilized for 15 min., a steady current will be applied as follows: 100% wire rated current for 30 min followed by a no-load period of 15 min.
- c) The test samples will be subjected to 100 cycles continuously.
- d) MVD will be measured while the test current is being applied and after the temperature has stabilized.
- e) Measurements will be recorded at the start of the first cycle and after every 10 cycles thereafter.

Requirements.—The voltage drop across the wire termination shall not exceed 150% of the original value.